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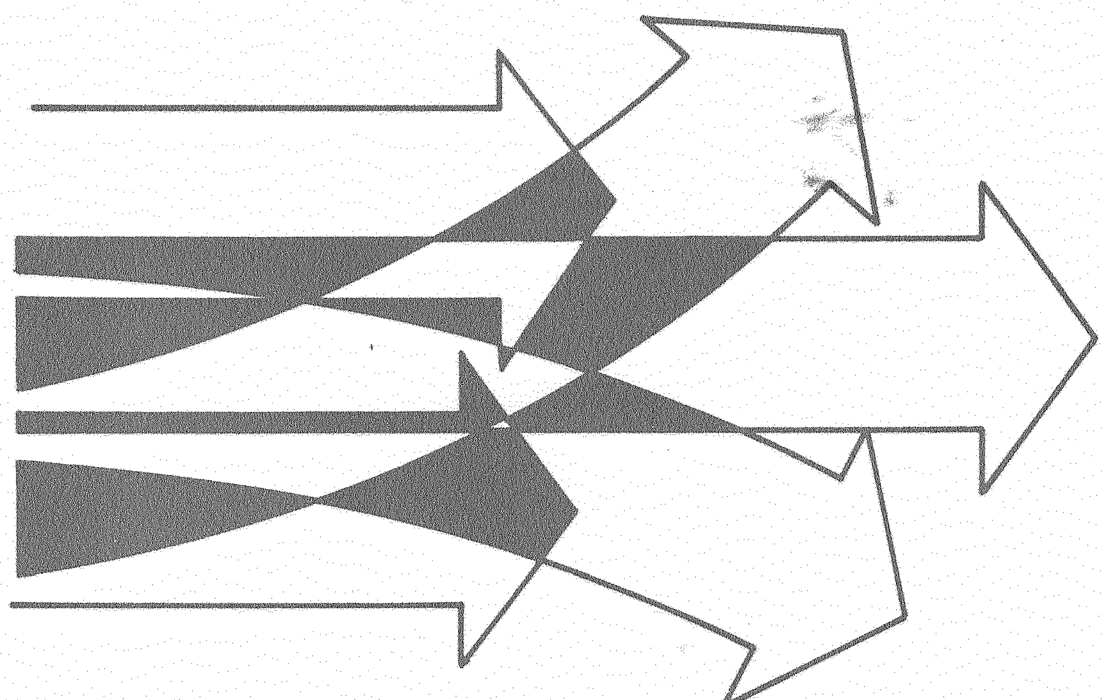
ENERGY
IN CALIFORNIA

ITS SUPPLY.... DEMAND.... PROBLEMS



THE RESOURCES AGENCY • STATE OF CALIFORNIA • JANUARY 1973

STATE OF CALIFORNIA
RONALD REAGAN, *Governor*

THE RESOURCES AGENCY
N. B. LIVERMORE, JR., *Secretary for Resources*

DEPARTMENT OF CONSERVATION
RAY B. HUNTER, *Director*

THIS REPORT IS A STUDY OF CALIFORNIA'S ENERGY SITUATION. COMMENTS SHOULD BE ADDRESSED TO THE DIVISION OF OIL AND GAS, 1416 NINTH STREET, SACRAMENTO, CALIFORNIA 95814.

ENERGY IN CALIFORNIA

COORDINATED AND PREPARED BY THE
CALIFORNIA DIVISION OF OIL AND GAS

1973

STATE OF CALIFORNIA—RESOURCES AGENCY

RONALD REAGAN, Governor

DEPARTMENT OF CONSERVATION

DIVISION OF FORESTRY
DIVISION OF MINES AND GEOLOGY
DIVISION OF OIL AND GAS
DIVISION OF SOIL CONSERVATION

SACRAMENTO, CA 95814
1416 Ninth Street

Honorable N. B. Livermore, Jr.
Secretary, Resources Agency
1416 Ninth Street
Sacramento, California 95814

Dear Mr. Livermore:

Transmitted herewith is "Energy in California," a report compiled by the Department of Conservation.

This report includes sections on demand for energy by the various market categories, supplies of energy currently available, and possible future supplies.

The project was coordinated by the Division of Oil and Gas, Department of Conservation. The projections contained in this report are based upon conditions affecting fuel supply and demand which currently exist in California.

Sincerely,

Ray B. Hunter

Ray B. Hunter, Director

FOREWORD

An energy crisis does exist. It exists at both the national level and state level. It does not exist at a global level.

There is no shortage of energy resources in the Nation, but there is a shortage of environmentally acceptable energy resources. And there is a shortage of inexpensive energy resources.

This report will examine California's indigenous and exogenous energy resources, demands for energy, and some of the problems associated with supply and demand.

Here's what has been said recently about energy:

"California is faced with an energy shortage and insufficient service by the mid-1970's if long-range and immediate planning steps are not taken by the legislature, public agencies and the electric utilities."

-California Public Utilities
Commission, 1972

"...almost any measure of well-being...increases in close proportion to the energy available per capita."

-Dr. Barry Commoner (1972)
Director, Center for the Biology
of Natural Systems, Washington
University, St. Louis, Mo.

"Many engineers in emission control areas have been concerned because almost every solution...has been energy-extravagant."

-Wayne Anderson (1972)
Chief of Propulsion System
Division of U. S. Army Tank
Command

"...there are plentiful resources around the world but economics and political forces keep them from being available. We have the technology and tools to recover more than we do but to recover the energy reserves we call "potential" we'll need better economics and technology."

-B. Abbott Sparks, Jr. (1972)
Publisher "Petroleum Engineer"

"...(There is) equal disregard shown by all candidates for office, news media, government officials, and just plain citizens - for the welfare of the corporations which find, transport, process and sell energy in the U. S."

-Professor A. J. Meyer (1972)
Economist, Harvard University

"...more and more people are becoming aware of the linkage between pollution, the hasty and wasteful consumption of limited resources, and the growth of energy consumption. The reaction of industry...has been largely negative."

-Raymond Sherwin (1972)
President, Sierra Club

"...history would indicate that any major industrial power, faced with exhaustion of its energy supplies and feeling itself strong enough to win would, I think, risk war to keep its economy functioning."

-Admiral Rickover (1972)

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SUMMARY

An energy crisis exists in California. It is not a physical shortage of energy, but rather a shortage of cheap, environmentally acceptable energy. In the time span of this report, 1970 to 1985, it is expected that total energy consumption will double. During 1970 oil and gas supplied 89 percent of our total energy requirements. By 1985 they will still supply 77 percent.

In 1970 California consumed oil at an average rate of 1.29 million 42-gallon barrels a day while producing only 950,000 barrels a day. At currently projected rates, by 1985 consumption will be 3 million barrels a day and our production will fall to 500 thousand barrels a day, forcing the importing of 2.5 million barrels of oil a day. It will be necessary to construct 1.3 million barrels a day of additional refining capacity, or by way of example, seven refineries the size of the giant Standard Oil Company of California Richmond facility.

The most dramatic change that will occur in California's energy consumption picture is the shortage of natural gas, and this will be severely felt by 1975. Although other energy sources--hydro, nuclear, geothermal, and coal--will play a role in satisfying our needs and filling the gas shortage void, oil alone will still supply more than half of our total energy needs in 1985.

The energy markets in California, in order of descending magnitude, are: Transportation, Industrial, Electric Utilities, Residential, and Commercial. The Transportation Market demands 36 percent of the total energy consumed and all of this is oil--nearly a million barrels a day. By 1985 Transportation demand will grow to 1.77 million barrels a day with motor gasoline making up 58 percent of the market. The Electric Utilities Market will exhibit a major change in energy mix during the period 1970-1985. Whereas natural gas presently supplies 51 percent of this market, by 1985 it will supply only 2 percent, a direct result of the natural gas shortage.

California presently has about 5.2 billion barrels of proven oil reserves, mostly onshore. In addition, there are 30 billion barrels of undiscovered oil which is presumed to exist due to favorable geologic conditions, 24 billion of which is in the offshore continental shelf area of California. With full-scale development of our offshore resources, California could produce over 2 million barrels a day from this area by 1985, double present state production. This, coupled with strong incentives for onshore development, could make California nearly independent of politically unstable foreign sources of oil which require deficit spending.

California now imports about three-fourths of its natural gas. In the face of declining domestic production, additional sources of gas will have to be found, either from new discoveries or from foreign liquefied natural gas. Small amounts of gas may be made available through gasification of coal before 1980. These alternative sources will cost at least three times the current price of domestically-produced gas.

Nuclear-generated electricity is expected to furnish 13 percent of the total energy demand by 1985. Hydropower and geothermal energy will make a lesser impact. The more exotic forms of energy, such as solar, nuclear fusion, tidal, and hydrogen, and equally exotic conversion systems, such as fuel cells and magnetohydrodynamics, are not expected to have any measurable impact on California's Energy Market by 1985.

Less than half the energy consumed in California does useful work. The remainder, equivalent to 1.3 million barrels of oil a day, is lost, mostly in the form of heat. The Transportation Market offers the greatest possibility of additional efficiency.

Over the last decade, there has been inadequate concern for a continuing sufficient supply of our prime energy resources--oil and gas. Other forms of energy were likewise treated with indifference. Actions taken by federal, state, and local governments have, in effect, reduced our energy supplies. The offshore drilling moratorium on state lands, coastline petroleum sanctuaries, emission standards that reduce engine efficiency, and other restrictive measures, such as the recently passed Coastline Initiative (Proposition 20), have a serious influence on the State's energy situation.

If projected trends hold, by 1985 California will have to import 8 times as much oil as we currently do, build 35 times more nuclear generating capacity than now available, import 5 times more electricity derived from coal than at present, maintain the maximum level of production of other energy sources, and construct the refineries, ports, and distribution systems necessary to make this energy available.

ENERGY IN CALIFORNIA

Energy is defined as the capacity for doing work. Nearly every human activity in modern society requires energy. Without energy our agricultural production would be at subsistence level, our transportation would be on foot, our communications would be by voice. There would be no cooking, heating, cooling, metals, glass, or plastics.

Energy resources available over the next several decades can be classed in two basic categories; stored solar energy in the form of fossil fuels (oil, gas, coal), and terrestrial energy in the form of falling water, geothermal resources, or nuclear reactions. Most of the basic energy used today is in the form of heat from burning fossil fuels. Much is converted into secondary forms, such as boiling water to make steam to turn a turbine to generate electricity to run a motor.

A very close relationship exists between energy consumption and the gross national product. The United States consumes, by far, more energy per capita than any other nation in the world, and consistent with this, has the highest gross national product of any nation in the world (Figure 1). Another dramatic example of our energy use is depicted in Figure 2 which shows that the United States has six percent of the world's population and yet consumes 35 percent of the world's energy.

Scope

The purpose of this report is to compile an inventory of indigenous and exogenous energy resources available to the State of California. The report will also deal with the energy demand over the next 15 years and will inventory actions and events which have affected California's energy supply.

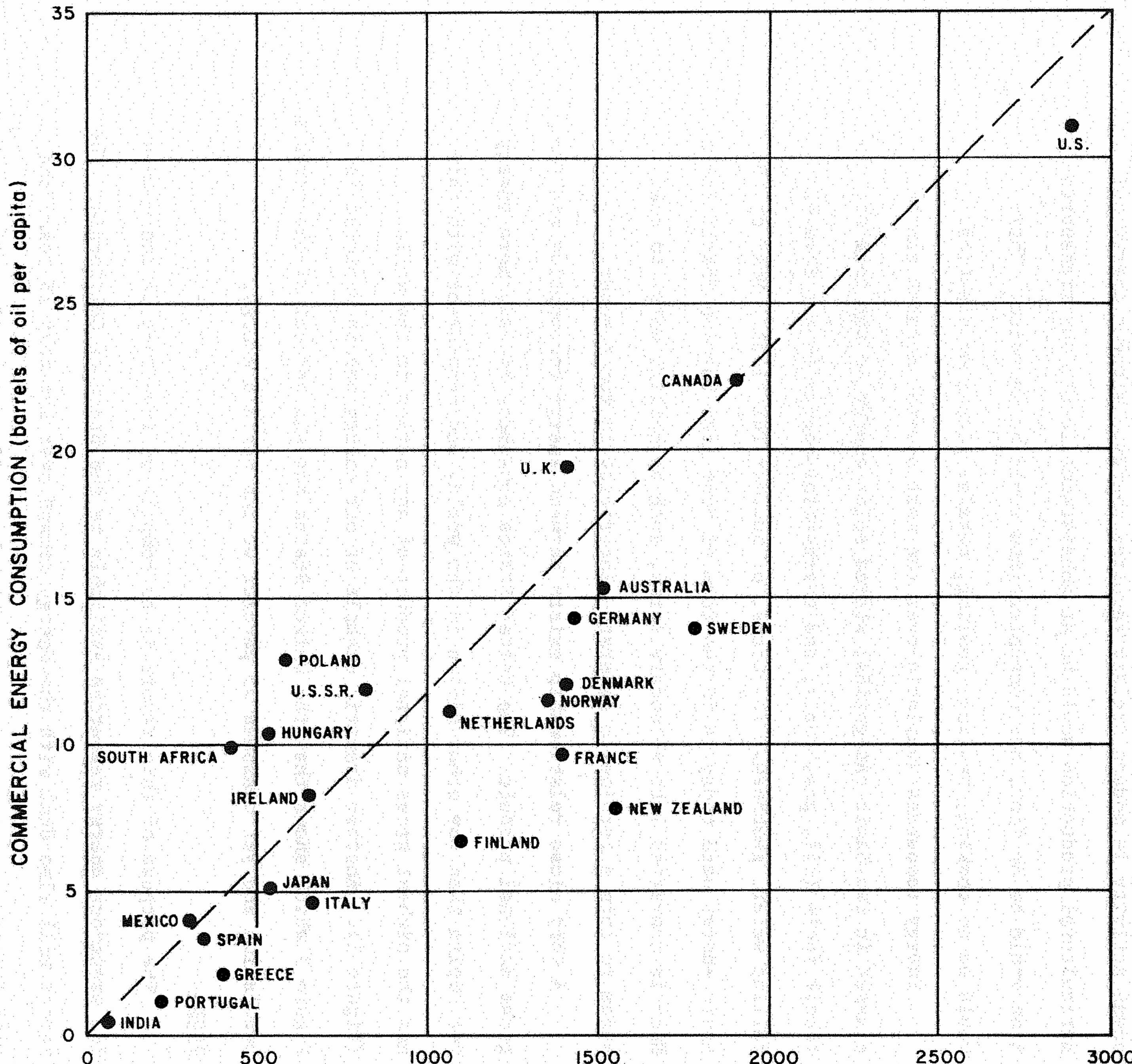


FIGURE 1 GROSS NATIONAL PRODUCT (dollars per capita) AFTER COOK, 1971

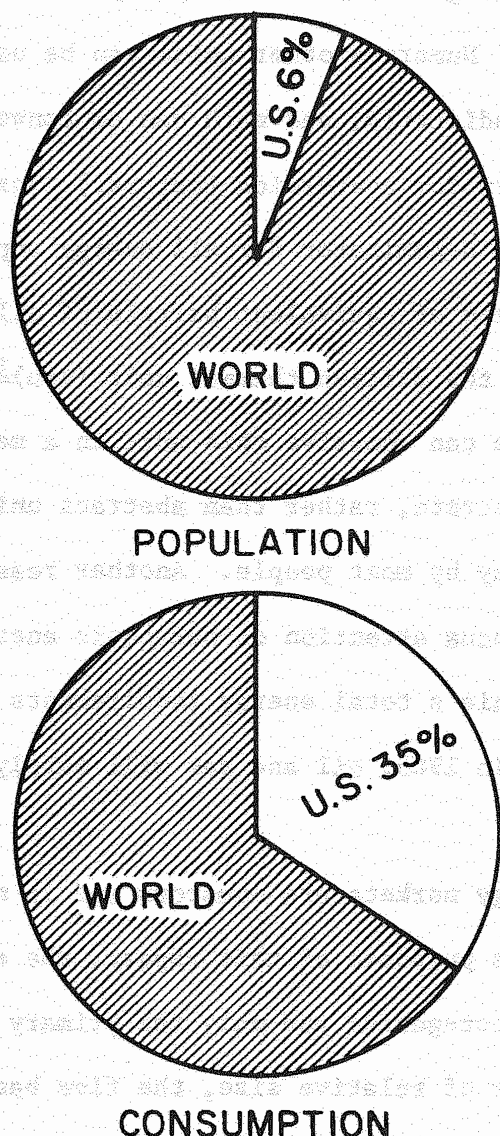


FIGURE 2 U.S. PORTION OF WORLD POPULATION AND ENERGY CONSUMPTION

Energy Measurement

The physicist measures energy in terms of joules or ergs, the engineer in horsepower or watts, the biologist in calories. Studies dealing with electrical generation usually express energy in terms of kilowatt-hours (KWH). Numerous other units can be used to measure energy, directly or indirectly, and each can be converted into one another. (See Glossary for conversion factors.) For the purpose of this study, the common denominator for all energy supply and demand figures will be in terms of equivalent barrels of oil. Although many studies on energy use the British thermal unit (Btu)1/ as a standard for comparison, few people can conceive this unit in a meaningful way, but a barrel of oil is a concrete, rather than abstract unit, and can be visualized in a general way by most people. Another reason for using a barrel of oil is to focus attention on our basic energy supply. Presently 89 percent of California's total energy requirements are furnished by oil and natural gas; in 1985, oil and gas will supply 77 percent.

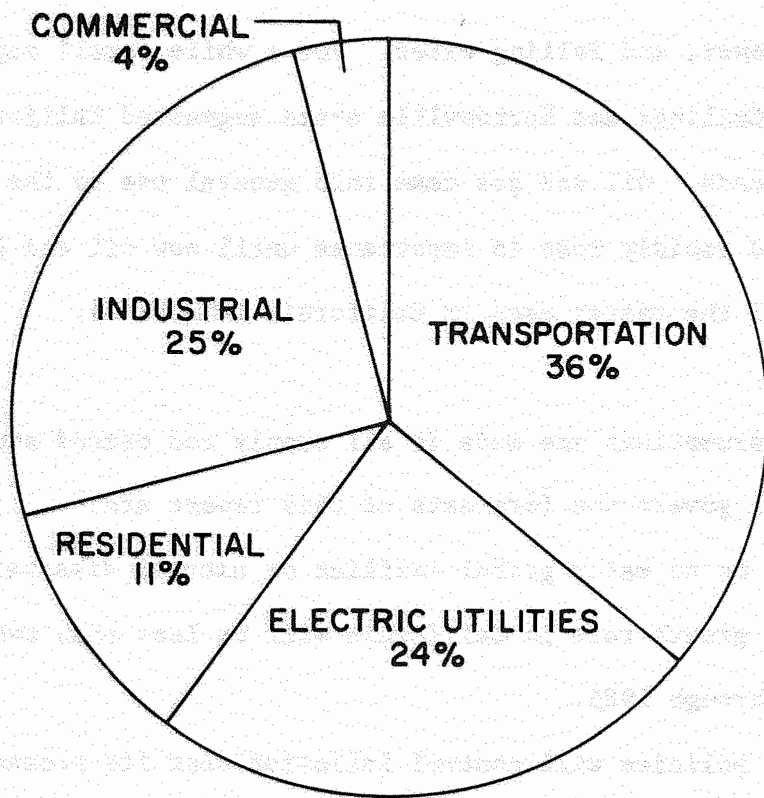
Basic Energy Markets

The various energy markets are numerous and in many cases overlapping; however, for the purposes of this report, the energy markets will be broken into broad categories and only the primary energy used will be computed. In order of relative size, the five basic markets are: Transportation, Industrial, Electric Utilities, Residential, and Commercial (Figure 3).

Electric utilities are only processors of basic energy resources and not final consumers. Basic energy sources are converted to electricity which is sold to ultimate consumers. Therefore, the portions of electric energy supplied to the various markets will not be assigned.

1/ A Btu is the amount of heat required to raise one pound of water one degree Farenheit.

CALIFORNIA
BASIC ENERGY MARKETS 1970



BASIC FUELS 1970

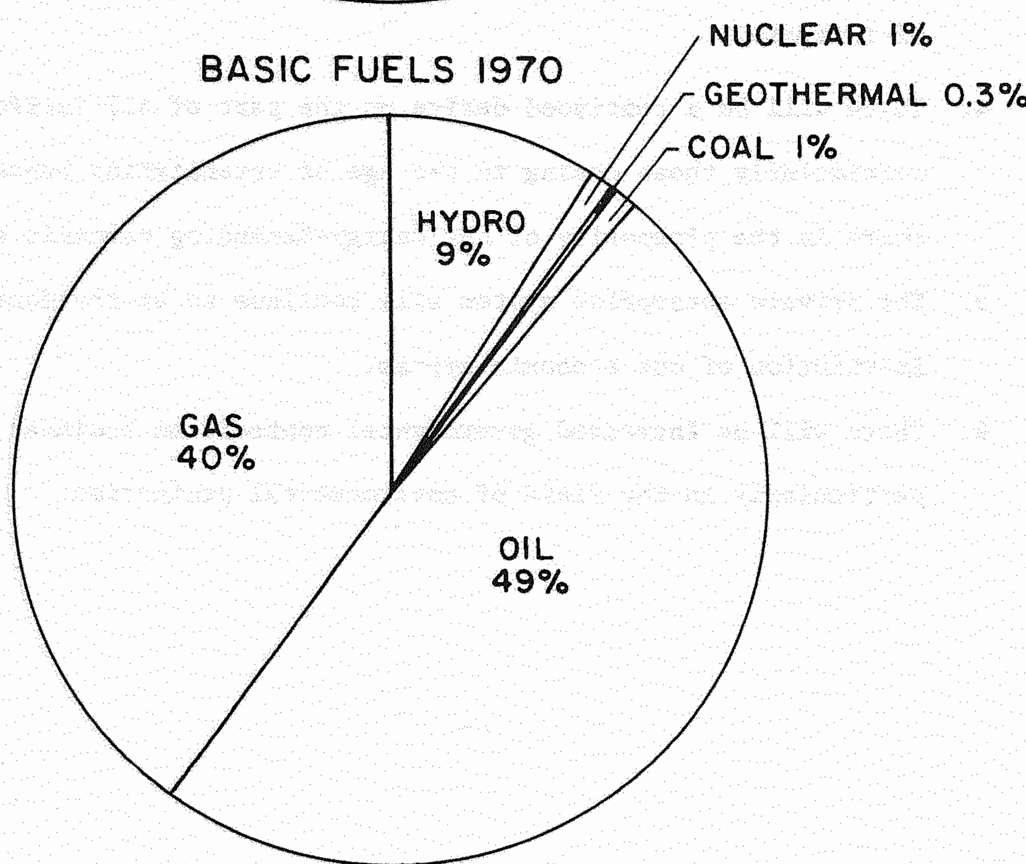


FIGURE 3

Basic Fuels

In the early years of California, the primary source of energy was wood, animal power, and falling water. For a while, small supplies of coal from the Coalinga and Nortonville areas augmented California's early energy needs. Oil and gas came into general use by the turn of the century and rapidly rose in importance until now oil and gas supply essentially all the energy used in California (Figure 3).

Assumptions

Certain assumptions are made in all supply and demand studies. Those that will govern the forecasts of this report are:

1. There will be no major global conflict or natural disaster.
2. Population growth rate in California will be less than two percent per year through 1985.
3. Government policies will control inflation near its present rate of increase.
4. There will be a continued desire on the part of all Californians, particularly those coming to the age of establishing households, to share in the prosperity of our energy-demanding economic system.
5. The private enterprise system will continue to be the dominant institution of our economic system.
6. There will be increased governmental controls on business activity, particularly in the field of environmental protection.

MARKET DEMAND

The demand for energy is governed by one factor - PEOPLE. Satiating the needs and desires of our population is the basic force motivating our economy. Since modern time there has been an uninterrupted growth of population, not only in the Nation but particularly in California. California's growth has been dramatic, and consequently our growth in energy demands has also been dramatic.

During the forecast period 1970-1985, it is estimated that the State's population will increase 30 percent, from 19.7 million to 25.6 million, 1/ (Figure 4). However, at current rate of growth, our energy demand will increase 100 percent, from 2.6 million equivalent barrels of oil per day to 5.2 million barrels.

A principal reason for the energy demand increase, which is more than three times the growth rate of the population, is the growth of the 20-34-age bracket. This age group is the largest consumer of goods and services, and commensurately, energy. Whereas this group now comprises 27 percent of the population, in 1985 they will comprise 34 percent. Over the next 10 years this group will increase at twice the rate of the population as a whole (Figure 5).

Another reason for the growth of California's energy demand is the continual increase in energy use per capita. Our ever-increasing standard of living goes hand in hand with energy consumption. In 1970, we used 48 equivalent barrels of oil per year per person; in 1985, we will use 74 equivalent barrels per year.

In all demand predictions there are varying degrees of uncertainty for the component segments, but there is a fairly good overall agreement on aggregate demand. A study which compared demand forecasts (Battelle

1/ California Department of Finance population projections.

CALIFORNIA POPULATION AND PROJECTED GROWTH

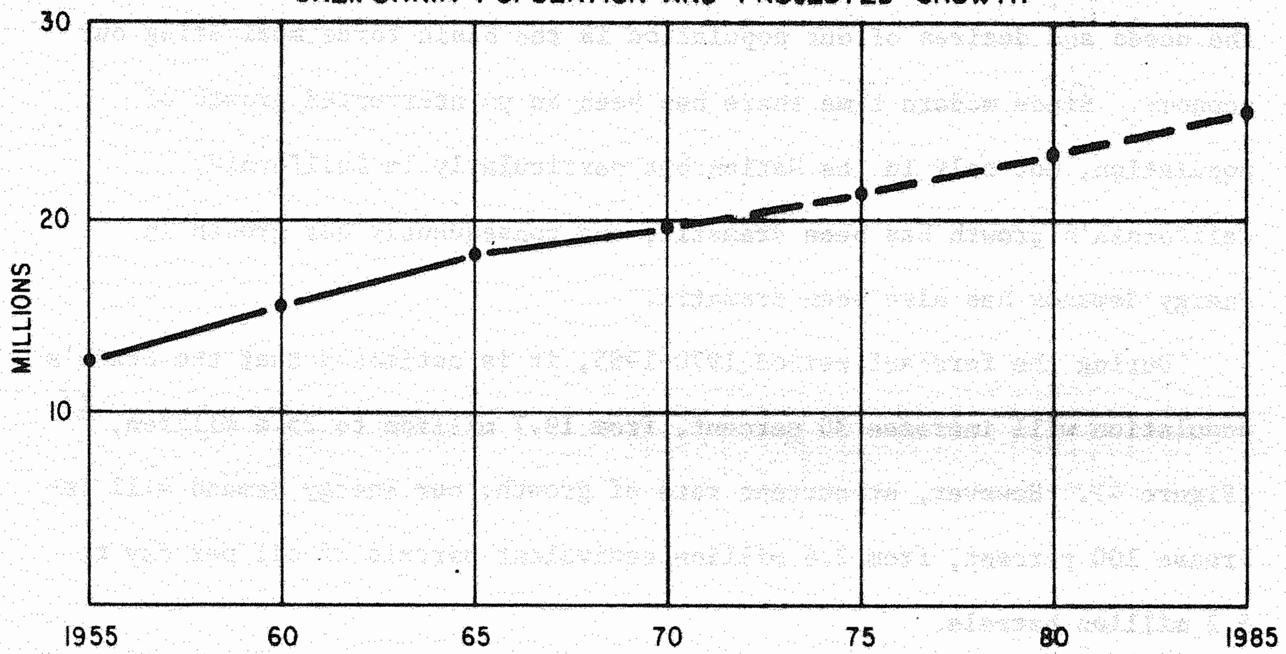
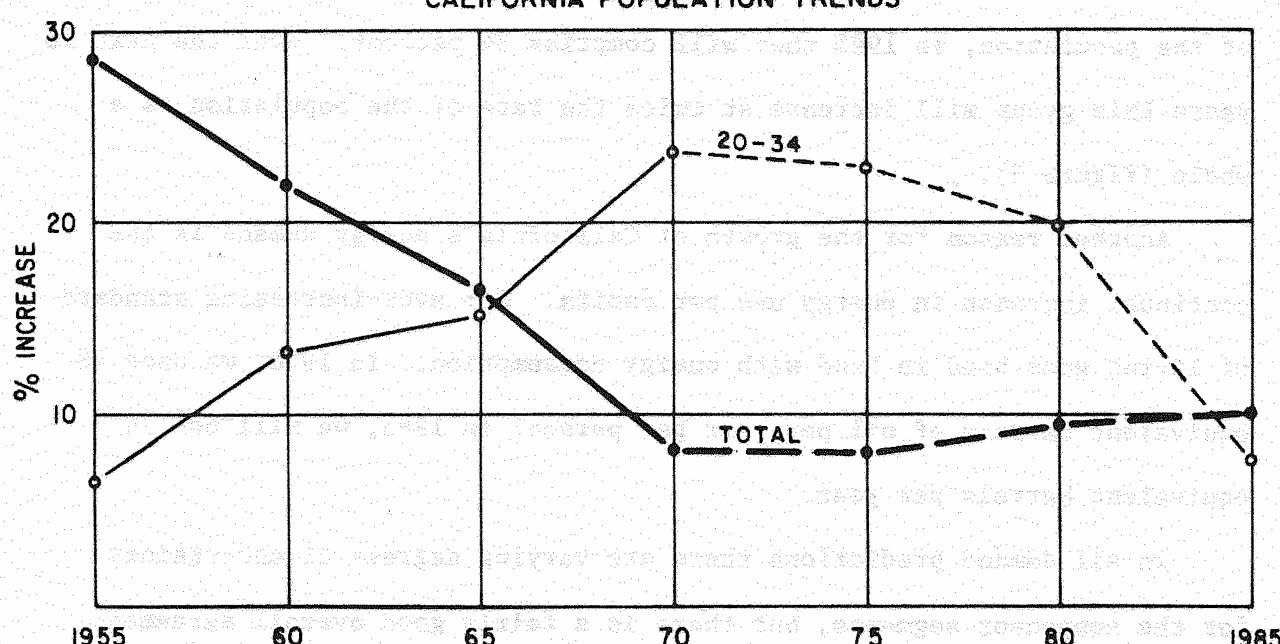


FIGURE 4

CALIFORNIA POPULATION TRENDS



20-34 AGE GROUP VERSUS STATE TOTAL

FIGURE 5

Memorial Institute, 1969) showed a general agreement of forecasts of total demand through 1980.

Most energy economists concur that predictions beyond 15 years are tenuous at best as changing technology becomes too large an unknown factor. In the long term, such other factors as production of synthetic oil and gas, and changes in cost relationships and lifestyles may also appreciably affect energy requirements.

Traditionally estimates of future demand have been on the low side. A study published in 1963 predicted U. S. oil yearly consumption at 5.34 billion barrels by 1980; this rate was reached in 1970. (Oil and Gas Journal, 1963). Component estimates are even more hazardous and subject to technological influence. Estimates of aviation gas consumption made during the late forties and fifties proved to be off by several orders of magnitude as the rapid increase in jet aircraft was not anticipated.

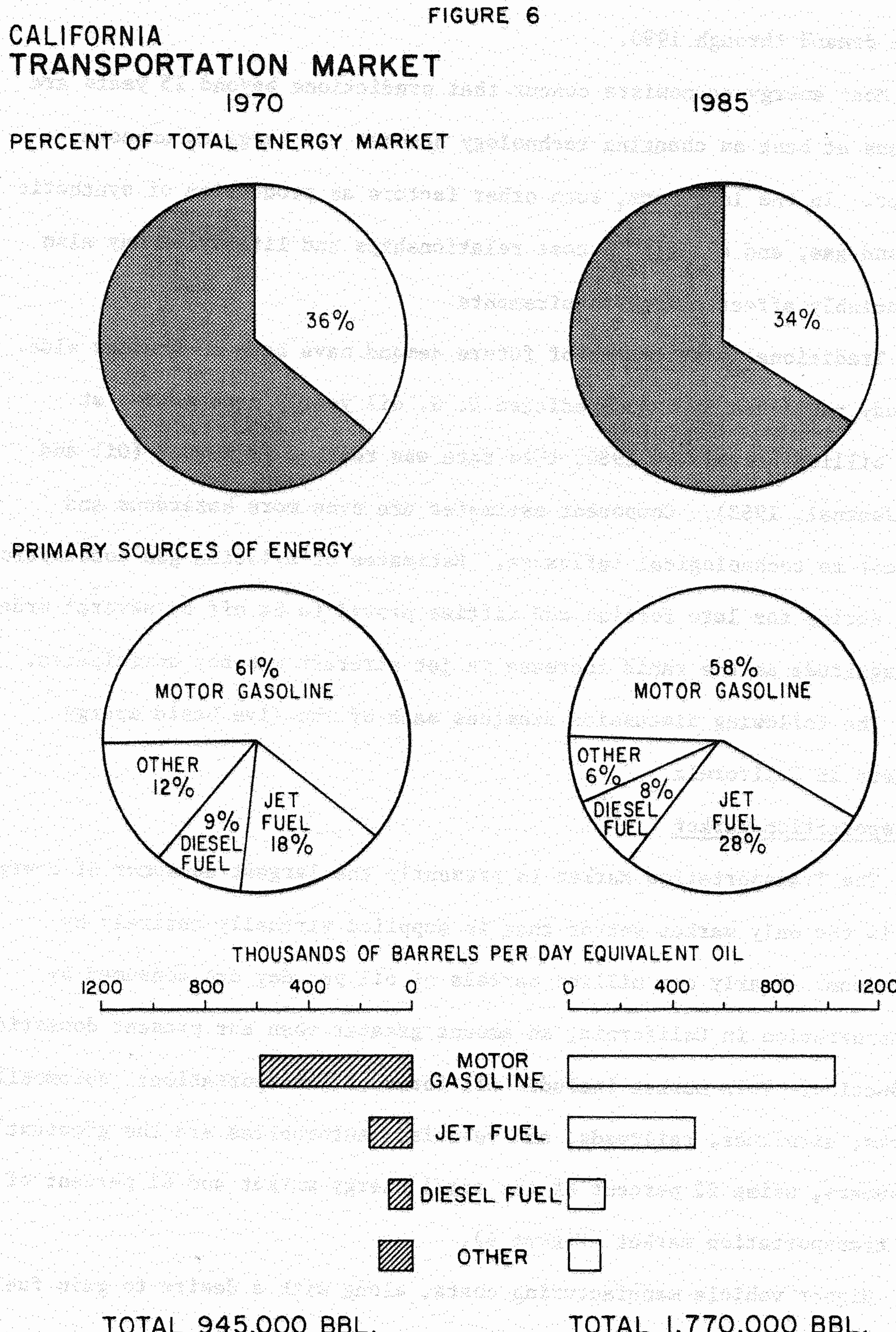
The following discussion examines each of the five basic energy markets in California.

Transportation Market

The Transportation Market is presently the largest consumer of energy and is the only market sector that is supplied virtually entirely by petroleum. Nearly one million barrels of oil per day are consumed by transportation in California, an amount greater than our present domestic production. This market includes all forms of transportation: automobiles, trucks, airplanes, railroads, and vessels. Automobiles are the greatest consumers, using 22 percent of the total energy market and 61 percent of the transportation market (Figure 6).

Higher vehicle manufacturing costs, along with a desire to gain fuel economy, may lead to a reduction in average car size, but conversely the efforts to limit polluting emissions from automobile engines will cause reduced operating efficiency. On balance then, the fuel requirements for

FIGURE 6


CALIFORNIA
TRANSPORTATION MARKET
1970
1985
PERCENT OF TOTAL ENERGY MARKET
36%
34%
PRIMARY SOURCES OF ENERGY
61%
MOTOR GASOLINE
OTHER
12%
9%
DIESEL FUEL
JET FUEL
18%
58%
MOTOR GASOLINE
OTHER
6%
8%
DIESEL FUEL
JET FUEL
28%
THOUSANDS OF BARRELS PER DAY EQUIVALENT OIL
1200
800
400
0
0
400
800
1200
MOTOR GASOLINE
JET FUEL
DIESEL FUEL
OTHER
TOTAL 945,000 BBL.
TOTAL 1,770,000 BBL.

automobiles will continue to rise proportionately to the number of cars unless the average size and use of accessories is reduced substantially.

The fastest growing segment of this market is commercial air transport. By 1985, the demand for jet fuel, according to present projections, will more than triple while other segments will roughly double.

Rapid transit systems, such as the recently completed Bay Area Rapid Transit, are not expected to be major consumers of energy by 1985. In the event that there is broad acceptance and major systems are operating in the Los Angeles area, the electrical energy used to power them will, for the most part, be derived from burning oil and gas.

Industrial Market

The Industrial Market includes factories, mills, processing plants, and other industry-type operations. The energy used is mostly in the form of heat for furnaces, drying ovens, and process steam. Five percent is in the form of raw materials for the manufacture of petrochemicals. Currently the industrial component accounts for 25 percent of the total market; by 1985, it will comprise 20 percent (Figure 7). This decrease will result as greater amounts of electricity are substituted for primary energy.

The demands of the Industrial Market are met almost entirely by natural gas and oil with natural gas presently being dominant. A small amount of coal is imported for use in a steel mill in Southern California. By 1985, the total industrial demand will increase by 62 percent.

Electric Utilities Market

Vast amounts of primary energy are used to generate electricity. This market ranks third in California as a consumer of energy. This is also the fastest growing market and by 1985, according to present projections, will rank as number two in comparison with the other markets. Its demands for energy will roughly triple (Figure 8).

FIGURE 7

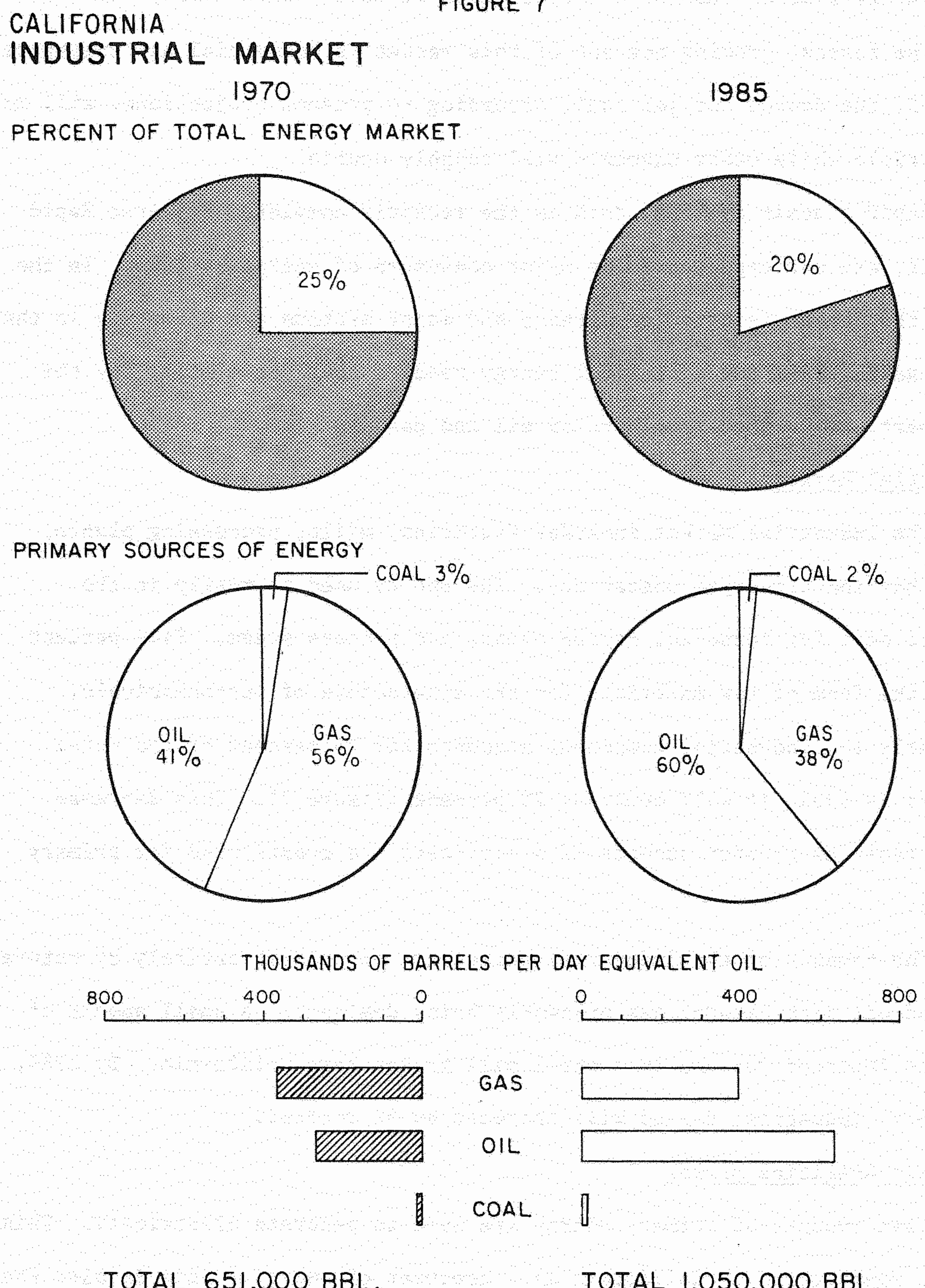
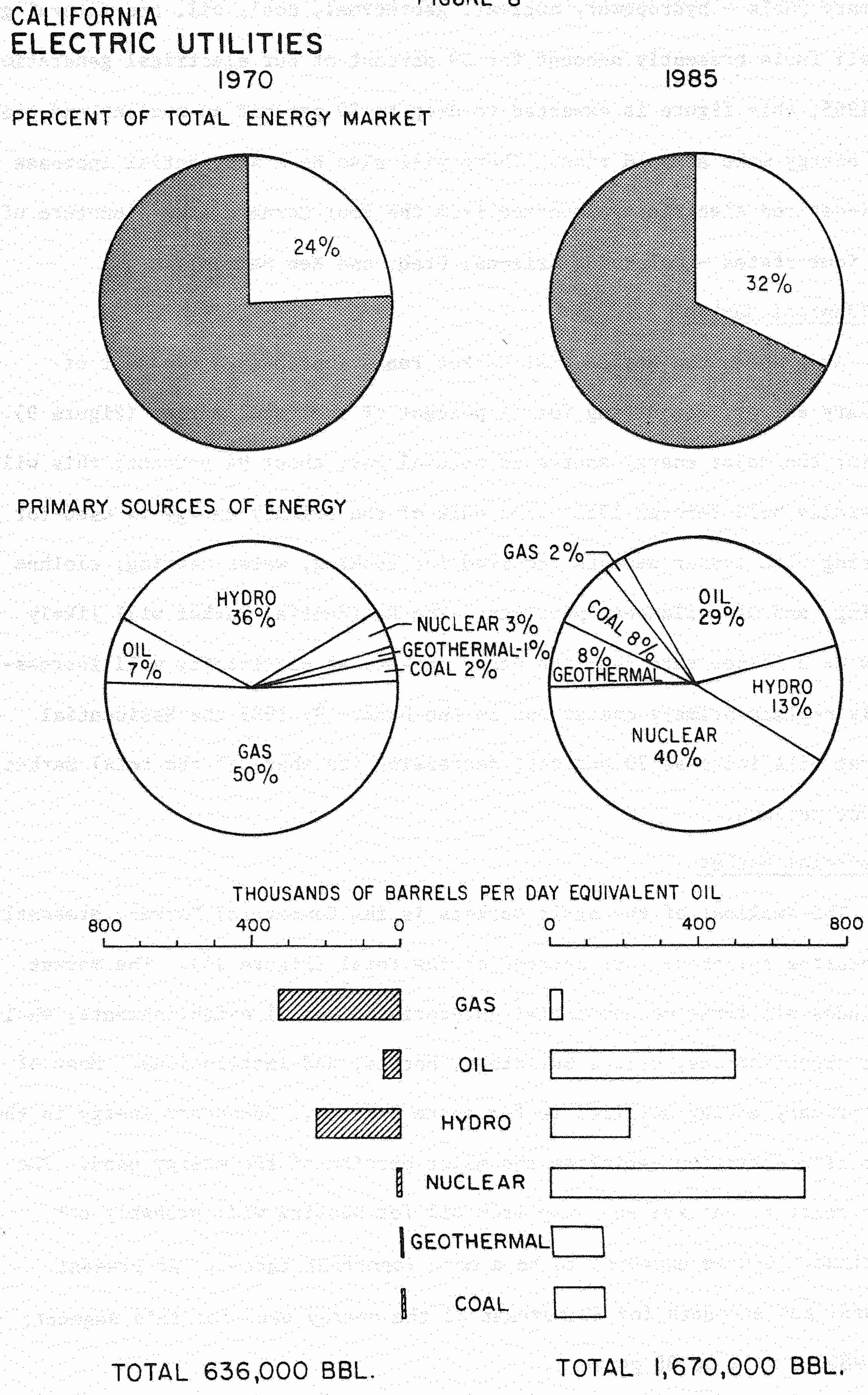

CALIFORNIA
INDUSTRIAL MARKET
1970
1985
PERCENT OF TOTAL ENERGY MARKET
25%
20%
PRIMARY SOURCES OF ENERGY
COAL 3%
COAL 2%
OIL 41%
GAS 56%
OIL 60%
GAS 38%
THOUSANDS OF BARRELS PER DAY EQUIVALENT OIL
800
400
0
0
400
800
GAS
OIL
COAL
TOTAL 651,000 BBL.
TOTAL 1,050,000 BBL.

FIGURE 8



CALIFORNIA
ELECTRIC UTILITIES
1970
1985
PERCENT OF TOTAL ENERGY MARKET
24%
32%
PRIMARY SOURCES OF ENERGY
HYDRO 36%
OIL 7%
GAS 50%
NUCLEAR 3%
GEOTHERMAL-1%
COAL 2%
GAS 2%
OIL 29%
COAL 8%
8% GEOTHERMAL
HYDRO 13%
NUCLEAR 40%
THOUSANDS OF BARRELS PER DAY EQUIVALENT OIL
800
400
0
0
400
800
GAS
OIL
HYDRO
NUCLEAR
GEOTHERMAL
COAL
TOTAL 636,000 BBL.
TOTAL 1,670,000 BBL.

Fortunately, electricity can be generated by a diverse selection of primary fuels - hydropower, nuclear, geothermal, coal, oil, and natural gas. Fossil fuels presently account for 59 percent of our electrical generation; by 1985, this figure is expected to drop to 39 percent as nuclear and geothermal energy make a rapid rise. There will also be a substantial increase in coal-derived electricity imported from the Four Corners area (juncture of the four states - Colorado, Arizona, Utah, and New Mexico).

Residential Market

At present the Residential Market ranks fourth as a consumer of primary energy, accounting for 11 percent of the total market (Figure 9). By far the major energy source is natural gas, about 94 percent; this will generally hold through 1985. The bulk of the primary energy is used for heating with lesser amounts required for cooking, water heating, clothes drying, and miscellaneous purposes. The Residential Market will likely grow at a lesser rate than the other markets as electricity will increasingly replace primary energy use in the home. By 1985 the Residential Market will increase 70 percent, decreasing its share of the total market by one percent.

Commercial Market

The smallest of the basic markets is the Commercial Market, presently accounting for about four percent of the total (Figure 10). The market includes all forms of commercial enterprise - retail establishments, wholesale organizations, office buildings, hotels, and institutions. Most of the primary energy utilized is for space heating. Secondary energy in the form of electricity satisfies the major portion of the energy used. The past shift to natural gas away from oil for heating will probably not continue. LPG is expected to be a more important factor. At present natural gas accounts for 89 percent of the energy used for this segment; by 1985 it will be 88 percent.

FIGURE 9

CALIFORNIA RESIDENTIAL MARKET

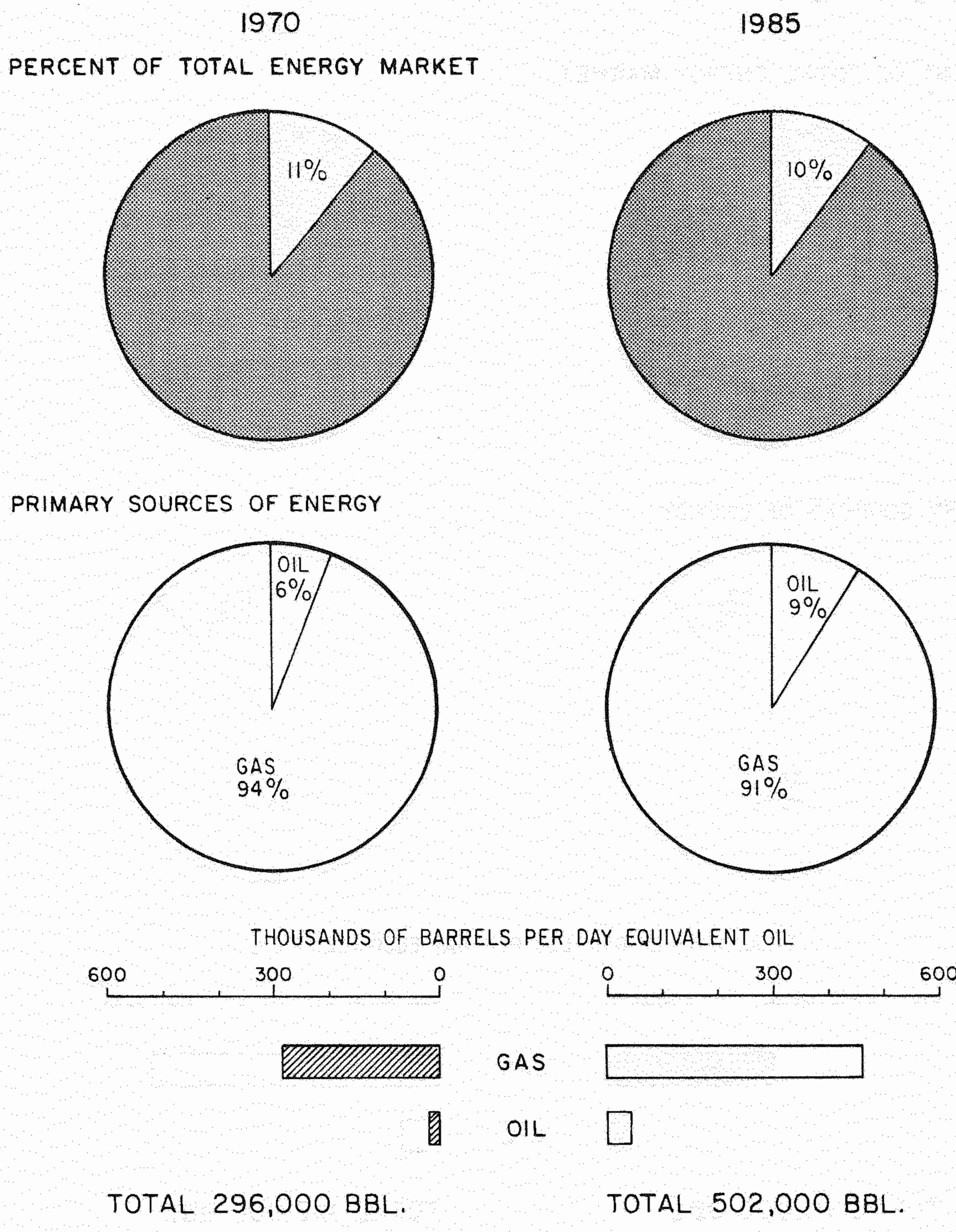
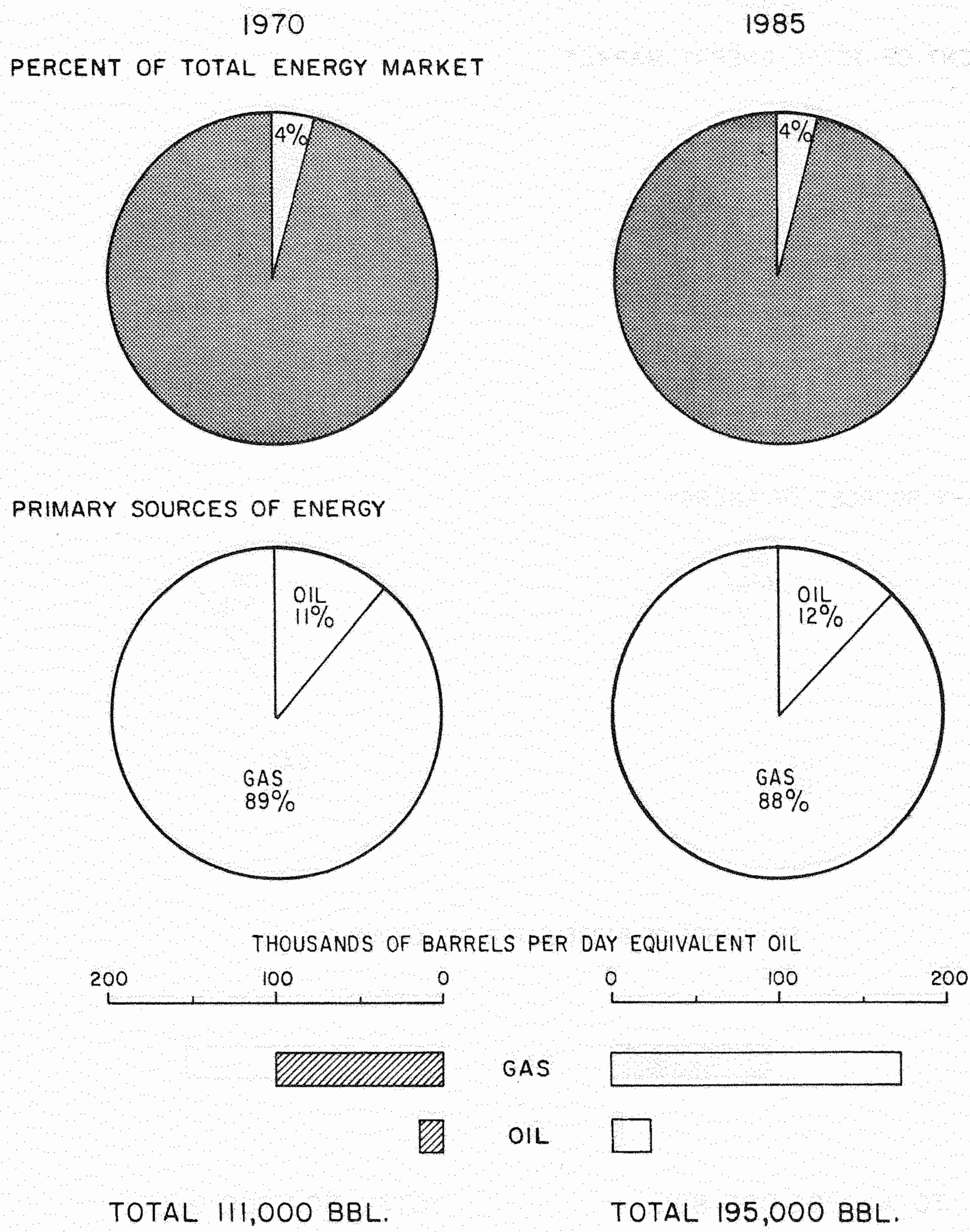


FIGURE 10

CALIFORNIA COMMERCIAL MARKET



The Five Markets Together

The primary energy requirements of the major markets in California for 1970 and 1985 are shown in Figure 11. This figure also shows that our overall demand for energy is expected to be about twice as large in 1985 as in 1970.

If these forecasts hold reasonably true, it is evident that the energy needs of the State, notwithstanding the Nation, will be enormous. The requirements of the Transportation and Electric Utilities Markets alone will represent two-thirds of the total market.

Even though the basic markets vary considerably in size, each one must be considered as important as the other because they are inextricably entwined. If any one is denied a fully adequate supply of energy, it will impair the State's economy and the people's standard of living.

Primary Sources of Energy Together

The primary sources of energy, their consumption, and expected demand are summarized in Table 1 in equivalent barrels of oil.

Oil is virtually the only energy source common to each of the five basic markets and is the only source used in the Transportation Market. By 1985 a small amount of natural gas and synthetic fuel derived from coal may be used in this market segment.

In 1970 oil alone accommodated 49 percent of California's energy need and by 1985 it is expected to accommodate 57 percent. This is a direct reflection of the decreasing availability of natural gas.

Natural gas and hydropower are the only basic sources that will remain essentially unchanged in consumption.

CALIFORNIA ENERGY CONSUMPTION AND DEMAND

By Major Markets

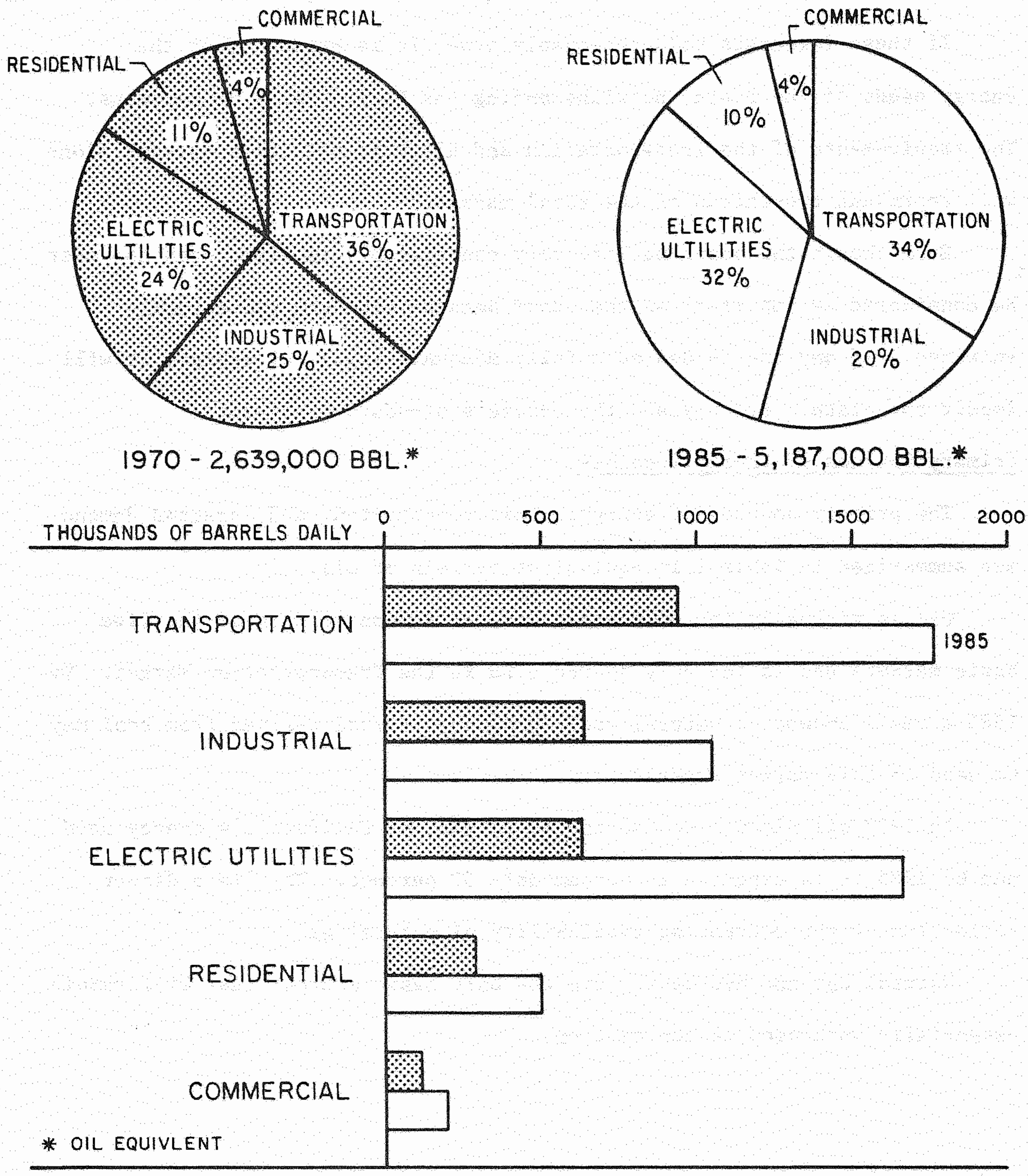


FIGURE 11

Table 1

California Energy Use
By Source

Thousands of Barrels Per Day Oil Equivalent

	1970	1975	1980	1985	Percent of Total 1970	Percent of Total 1985
Petroleum	1,287	2,020	2,490	2,971	49.0	57.0
Natural Gas	1,063	1,087	1,090	1,049	40.0	20.0
Hydro	230	225	222	212	9.0	4.0
Nuclear	19	58	238	677	0.7	13.0
Geothermal	8	16	67	130	0.3	3.0
Coal	32	55	106	148	1.0	3.0
Total	2,639	3,461	4,213	5,187	100.0	100.0

ENERGY SUPPLY

Because energy is absolutely essential to the welfare of California and the Nation as well as an indispensable ingredient for our national security, the continuing availability of adequate supplies is vitally important. All segments of society, small business, private industry, and most of all, government, need to be concerned because an energy crisis does exist. As Table 1 shows, oil and natural gas will continue as the mainstays of our energy supply through 1985. The time lag associated with the development of other energy resources, seven to eight years for nuclear, means that petroleum must provide the major portion of our energy needs. As Table 2 denotes, there are vast proven reserves of the principal fuels--oil, gas, and coal--on a world basis and these fuels supply 96 percent of the Nation's energy demand and 90 percent of California's demand. However, at the present and projected domestic rates of consumption, proven national reserves of oil and natural gas will be short-lived. California's proven reserves and daily production of these two important fuels are rapidly diminishing. The last major oil discovery was in 1965 in the McKittrick area in Kern County. Our oil reserves have declined to about 5.2 billion barrels and our gas reserves to about 7.5 billion Mcf. (Table 3). Daily oil production has declined from a high of 1,022,000 barrels in 1968 to 892,000 barrels in 1972. Natural gas production also fell; from a high of 1,960,000 Mcf. per day in 1968 to 1,420,000 Mcf. per day in 1972.

In the light of projected demand, these statistics reveal that California will become increasingly reliant on foreign imports. The amount of reliance will depend largely upon national and state policies and their role in encouraging efforts to enhance or restrict domestic

TABLE 2

PROVEN RESERVES - OIL, GAS, AND COAL

1971

	OIL	GAS		COAL	
	(Billion barrels)	Billion Mcf.	Billion equiv. bbls. oil	Billion short tons	Billion equiv. bbls. oil
California	5.2	7.5	1.33	.078	.4
United States (includes North Slope)	37.0	257.0	45.6	1,605.0	7,240.0
Free Foreign	474.4	897.0	159.4	3,300.0*	14,900.0

*Total Foreign

Table 3

CALIFORNIA OIL AND GAS RESERVES

1971

Million Bbls. or Mcf.

	Primary Reserves			Secondary Reserves		Potential Reserves
	Oil (Bbls.)	Wet Gas (Mcf.)	Dry Gas (Mcf.)	Oil (Bbls.)	Wet Gas (Mcf.)	Oil * (Bbls.)
Onshore						
Urban	1,635	938	6	478	60	1,175
Rural	2,710	2,972	3,002	296	15	5,575
Offshore						
State	756	275	302	66	8	3,590
Federal	99	146	-	125	11	20,000
TOTALS	5,200	4,185	3,310	965	94	30,440

DEFINITION OF TERMS:

Primary Reserves - Reserves recoverable under currently active operations.

Secondary Reserves - Additional reserves recoverable by application of known stimulation methods to proven fields.

Potential Reserves - Undiscovered recoverable reserves presumed to exist due to favorable geology.

* Includes gas equated to oil.

exploration and development.

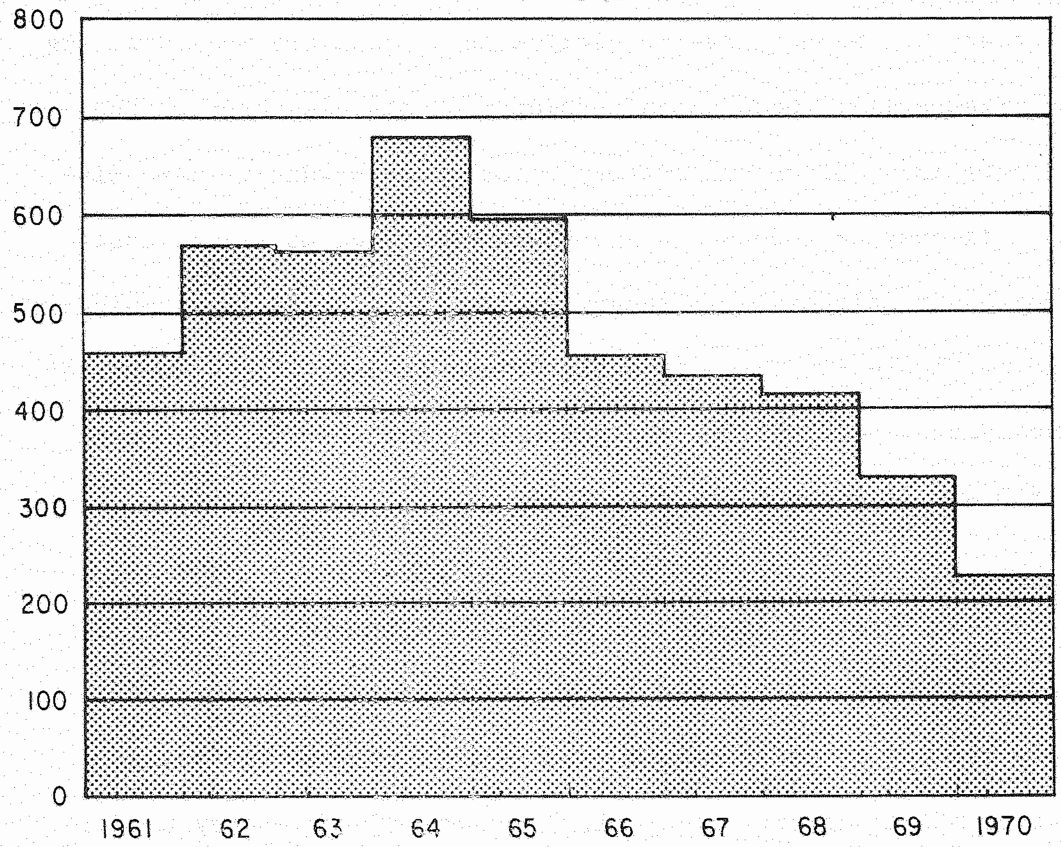
Although California has a large potential reserve of oil and gas (Table 3), there has been a drastic decline in exploratory well drilling since 1964 (Figure 12). Geophysical exploration has also been on the decline (Figure 13). Since exploratory efforts are needed to make discoveries, it is easy to understand why there have been no significant oil discoveries in California in recent years. This trend is graphically illustrated on Figure 14, which is a historical account of the amount of oil reserves discovered. Thirty-one percent of the oil was discovered prior to 1910 and 91 percent prior to 1940.

Oil

In 1970, California consumed oil at an average rate of 1.29 million barrels a day while producing only 950 thousand barrels per day. Oil comprised 49 percent of California's total energy supply, including 100 percent of our transportation fuel, 7 percent of our energy used in households and commercial establishments, 41 percent of our industrial energy, and 7 percent of the energy input for electrical power.

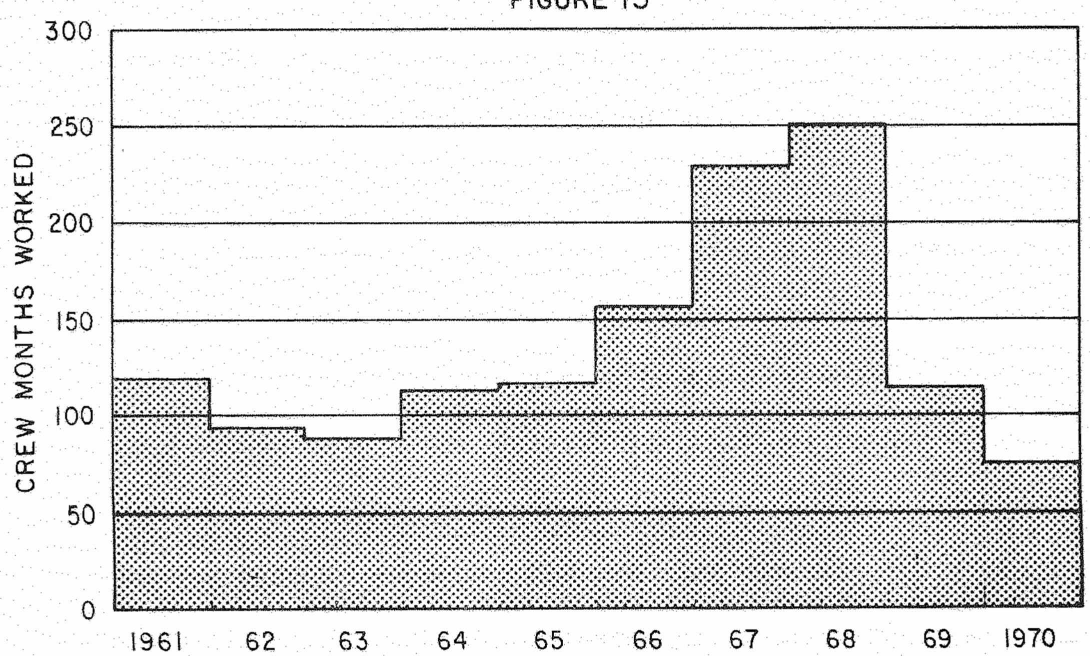
Projections of demand growth rate indicate an ever-increasing need for oil products. However, within the probable range of future California requirements, one conclusion seems obvious. Without a major, positive change in our domestic oil-finding and producing efforts, California will certainly depend more and more on outside sources for its oil supplies. This dependency on foreign sources of supply presents another set of complex problems. Two of the foremost foreign import shortcomings are the unreliability of the source and the burgeoning balance of payments deficit. It has been estimated that by 1985 the United States may have to import more than one-half of its petroleum supply. This will place the Nation in a highly vulnerable position. Many of the foreign

FIGURE 12



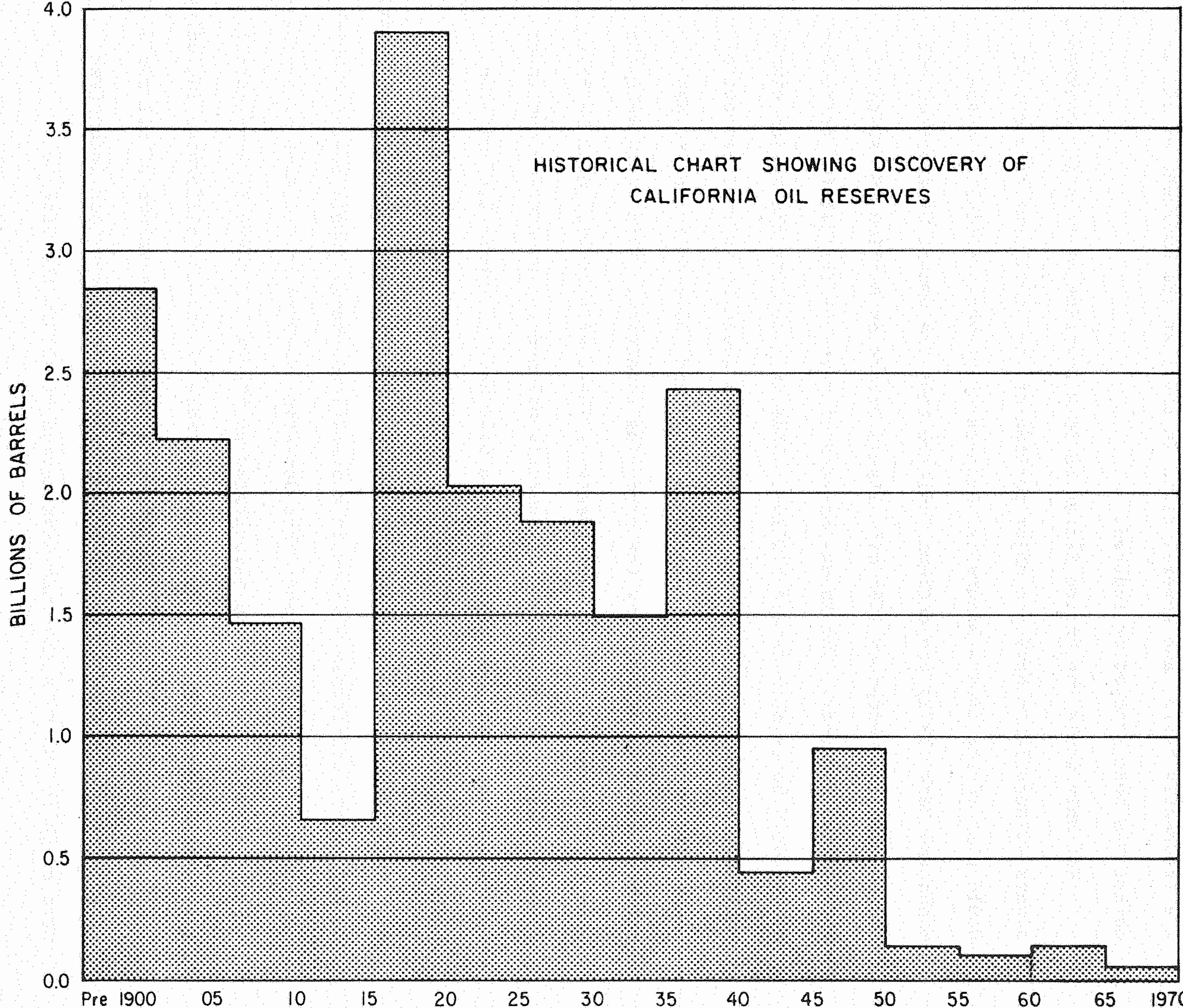
EXPLORATORY WELLS DRILLED IN CALIFORNIA, 1961-1970

FIGURE 13



GEOPHYSICAL ACTIVITY IN CALIFORNIA, 1961-1970

FIGURE 14

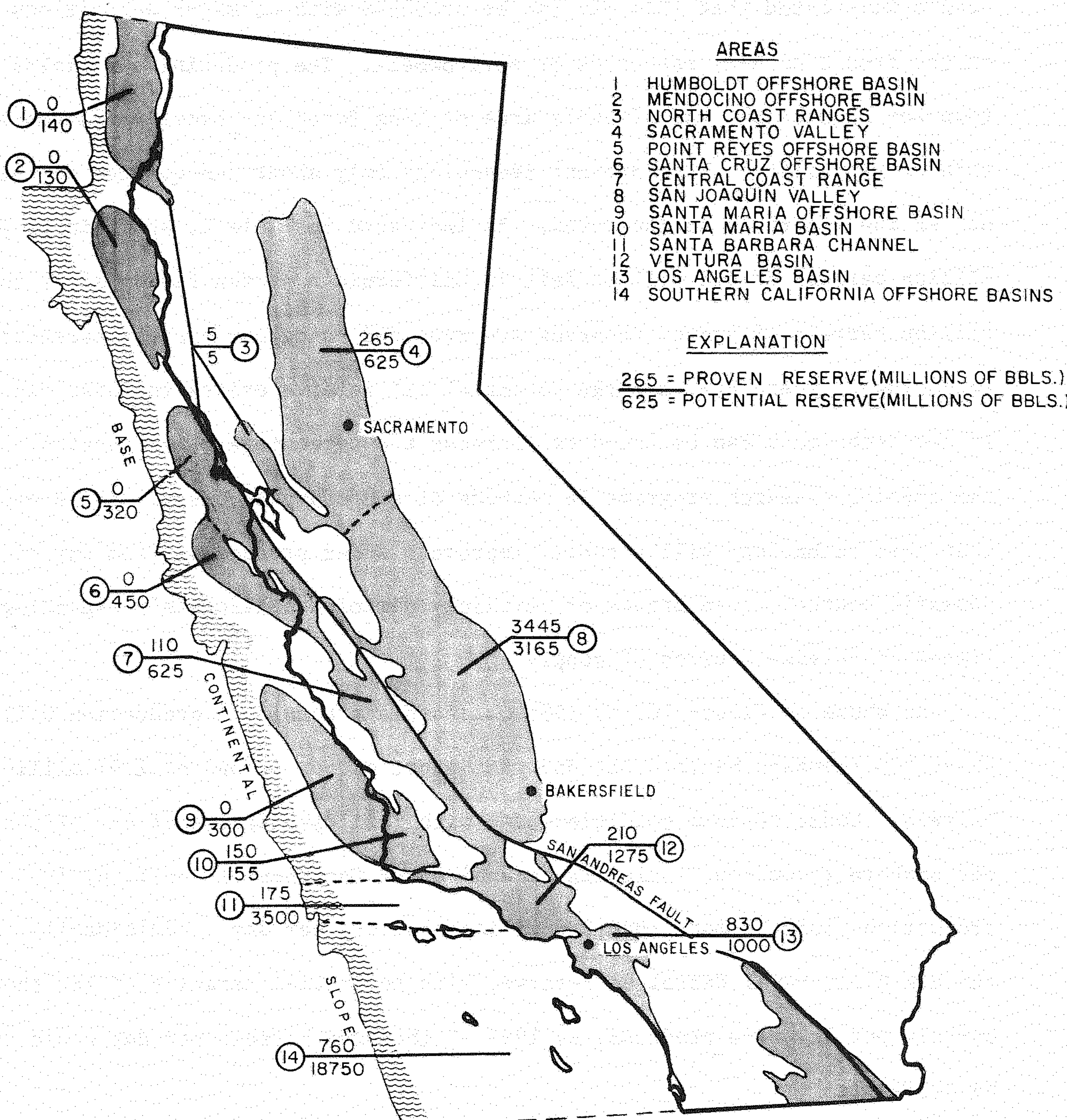

HISTORICAL CHART SHOWING DISCOVERY OF
CALIFORNIA OIL RESERVES
BILLIONS OF BARRELS
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Pre 1900
05
10
15
20
25
30
35
40
45
50
55
60
65
1970

producing areas have long been the scene of strife and turmoil which poses the continuing possibility that the movement of oil to market may be halted by foreign governmental action. Threats to cut off or reduce the supply are frequently heard, and several times in the past the movement of oil to market has been stopped or reduced.

Not only would the United States be in a position of constant weakness, always vulnerable to having a major portion of its supply cut off, but it would also suffer from a monumental balance of payments deficit. Chase Manhattan Bank (1972) projections indicate that the amount of imported oil and natural gas needed by 1985 will likely create an outflow in excess of $30 billion per year. The annual balance of payments deficit for petroleum alone could be as much as $25 billion. This is a deficit the Nation simply could not tolerate. Because the United States would be an importer out of necessity, we would have no bargaining power and would be forced to pay whatever price is demanded by the producing countries. This could make the balance of payments deficit even greater. These effects will also be felt by California. If the decline of domestic oil and gas production continues at its present rate, by 1985 California will have to import 2.47 million barrels of oil or more than 83 percent of its supply; the major source will be the Eastern Hemisphere unless the Aleyska pipeline is constructed to Valdez. In any event, California will be in a precarious energy supply position which certainly underscores the tenet that domestic reserves of oil must be exploited.

As shown on Table 3 and illustrated on Figure 15, there is a potential recoverable reserve of over 30 billion barrels of oil in California, including the Outer Continental Shelf. Therefore, a considerable volume of oil could be added to California's present proved reserve if appropriate incentives were given to insure a thorough examination of all of the State's

FIGURE 15
MAP SHOWING PROVEN AND POTENTIAL OIL AND GAS RESERVES FOR 1971



ADOPTED FROM NPC, 1970

potential oil-producing sedimentary basins, whether located in offshore, urban, or rural areas. Particular emphasis should be placed on the offshore areas where some 25 percent of our present supply is obtained and where over 75 percent of our potential reserves exist. We must also be cognizant of the fact that about 30 percent of our proven reserves of oil is found in urban areas, and that it has been demonstrated that this oil can be produced without major deleterious affects on the area's natural esthetics or environment. The producing oil fields in downtown Los Angeles and the offshore area of Long Beach are excellent examples of this compatibility. With present technology only about one-quarter of the total oil in the reservoir is recovered. As indicated in Table 4, approximately 60 billion barrels of oil will be left in California's proven fields after the 5.2 billion barrels of proven reserves are produced using our present extraction technology. Therefore, a large potential oil reserve exists in these old fields if new techniques can be found to increase the percentage of extraction. Industry has ongoing research programs in methods of secondary recovery. It is expected that this technology will steadily improve. Added production from any of these domestic sources could negate or certainly diminish California's expanding reliance on outside sources of supply.

As shown on Figure 16, by 1985 California's total oil production will be about 500 thousand barrels per day, far short of our demand of 2.97 million barrels. Under optimum conditions and with full development of our offshore and onshore resources, including Federal Outer Continental Shelf, by 1985 our production could be more than 2.0 million barrels per day. Additionally, if the Elk Hills Naval Petroleum Reserve, with an initial capacity of 160 thousand barrels per day were produced, by 1985 55 thousand barrels per day would still be available.

Table 4

CALIFORNIA OIL AND GAS INVENTORY

1971

Million Bbls. or Mcf.

	REMAINING OIL AND GAS IN PLACE		
	OIL (Bbls.)	WET GAS (Mcf.)	DRY GAS (Mcf.)
Onshore			
Urban	27,384	4,984	11
Rural	31,799	3,336	3,601
Offshore			
State	5,683	341	172
Federal	732	179	-
TOTAL REMAINING	65,598	8,840	3,784
CUMULATIVE STATE PRODUCTION (Incl. Federal)	15,787	19,216	6,365
TOTAL ORIGINAL OIL & GAS IN PLACE	81,385	28,056	10,149

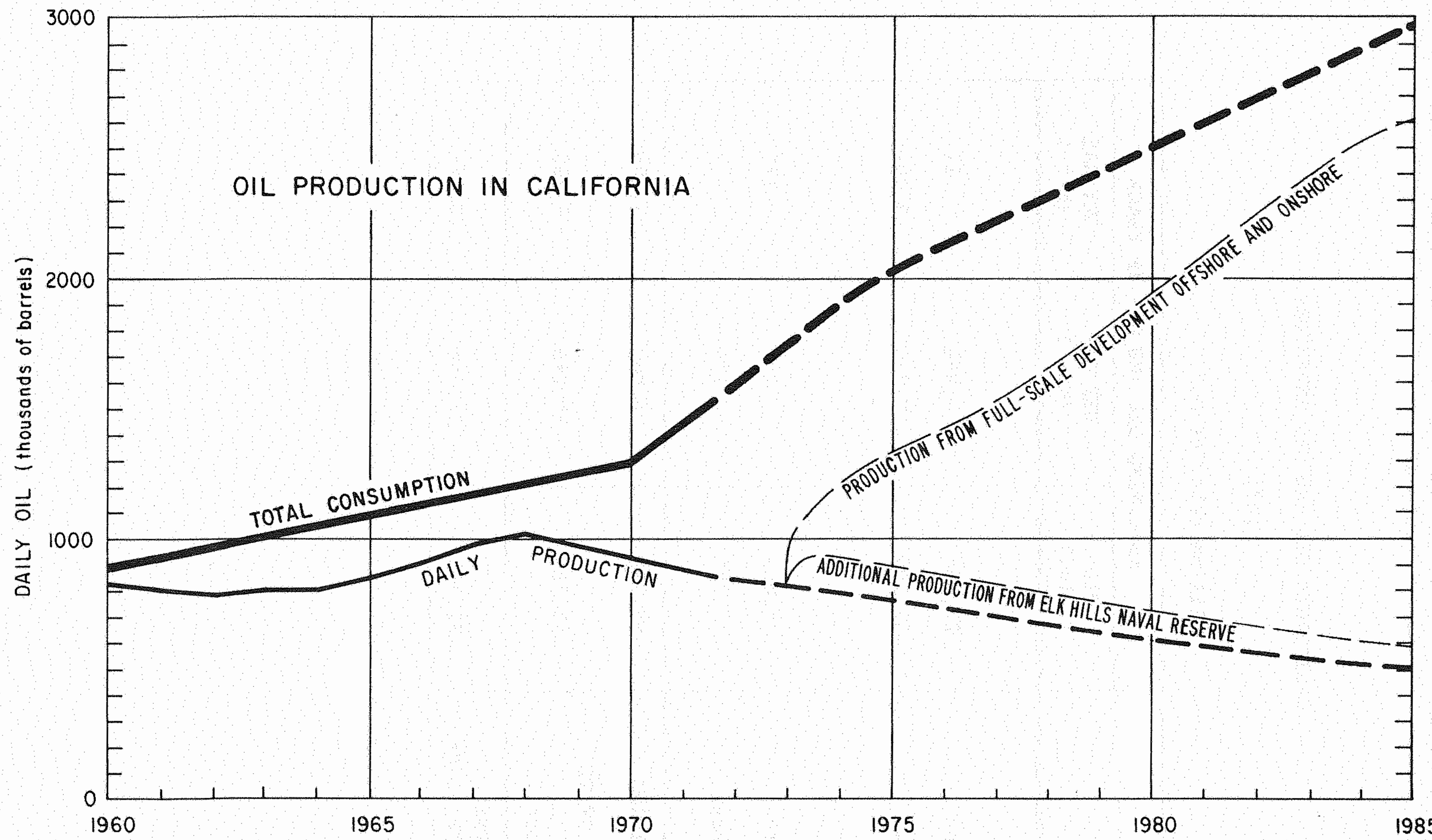

OIL PRODUCTION IN CALIFORNIA
DAILY OIL (thousands of barrels)
3000
2000
1000
0
1960
1965
1970
1975
1980
1985
TOTAL CONSUMPTION
DAILY
PRODUCTION
PRODUCTION FROM FULL-SCALE DEVELOPMENT OFFSHORE AND ONSHORE
ADDITIONAL PRODUCTION FROM ELK HILLS NAVAL RESERVE

FIGURE 16

By 1985 then, California's production from all sources could be as much as 2.6 million barrels per day. This would make our daily oil deficit only 370 thousand barrels as opposed to 2.47 million barrels if we follow our present course.

This, coupled with California's share of the 2.0 million barrels per day expected from the Alaska North Slope, could make California essentially independent from unstable foreign supplies through 1985.

It is possible that alternate sources of oil from coal or oil shale could provide some oil to California, but it will be 15 years before we have the capability to produce significant amounts of oil from these resources, and California has no oil shale or significant deposits of coal. Therefore, any products from these sources would have to be imported and with the current requirements of the other states involved, there is no assurance that California would receive any of these products.

Regardless of where we obtain our oil, it still has to be refined to be of use. To process our 1985 demand, California's refining capacity of about 1.7 million barrels per day will have to be increased by about 70 percent. This means that seven new refineries the size of the giant Richmond facility would have to be constructed. This number will be even larger if California continues to refine products for use in other western states.

Gas

Natural gas provides 40 percent of California's total energy requirements. It supplies approximately 94 percent of the residential and commercial energy needs, 50 percent of the requirement of steam electric plants, and 56 percent of the industrial demand.

The emphasis being placed on improving our air quality, particularly in the Los Angeles region, will further accentuate demand for natural gas because of its clean-burning qualities. During the last few years, demand for natural gas has exceeded the growth rate demand for total energy. However, an acute shortage already exists which will preclude further growth. The supply will remain nearly static through 1985 with oil making up the difference between supply and demand.

Although California imports three-fourths of its natural gas needs, a strong indigenous base is still important. California's total domestic proved reserves of natural gas now available to our markets has been declining since 1963. As of December 31, 1971, the total proved reserve of natural gas in California was approximately 7.5 billion Mcf. (Table 3). Our present rate of consumption is 5.7 million Mcf. per day or 1.1 million equivalent barrels of oil. California production is steadily declining and by 1985 will be about 1.0 million Mcf. per day (Figure 17), or only 17 percent of our demand compared to 28 percent in 1970. If new discoveries of natural gas are not found to augment our reserves, greater shortages will surely prevail. Figure 18 is a historical account of the discovery of California gas reserves.

California's gas production comes from two sources, that which is produced from gas fields (dry gas) and that which is produced in association with oil (wet gas). There is a large potential reserve of both wet and dry gas that lies undiscovered in California's major hydrocarbon-producing basins. Generally, the discovery of a large oil reserve means the discovery of a large gas reserve, so if oil drilling is resumed in offshore areas, substantial reserves of gas will be found. In the Sacramento Valley, the source of most of our dry gas supply, there is an estimated gas reserve of 625 million barrels of equivalent oil. Steps must be taken to enhance the exploration and development of this undiscovered resource. If the rate of natural gas development is not accelerated, then alternate methods of providing supplemental supplies of gaseous

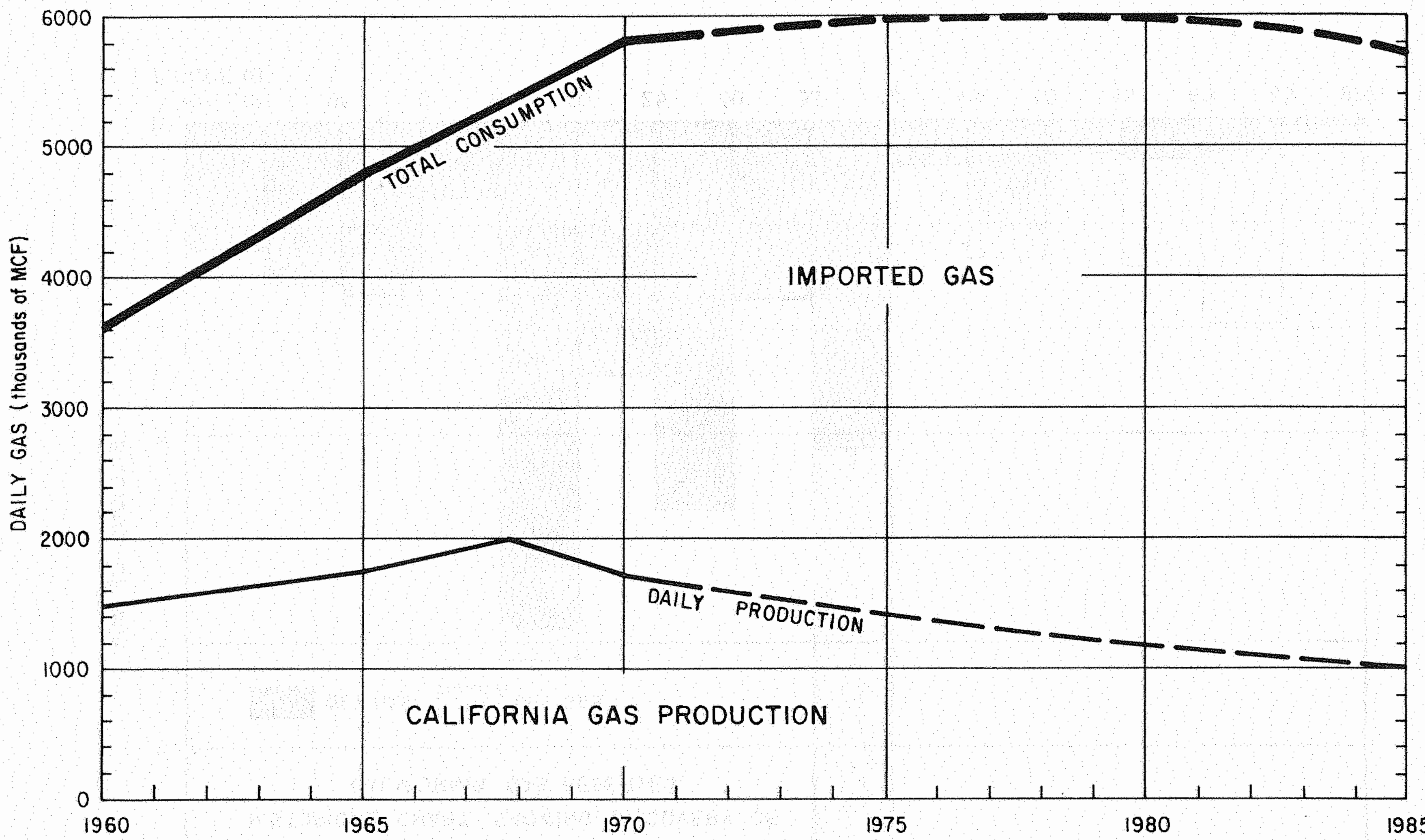

DAILY GAS (thousands of MCF)
6000
5000
4000
3000
2000
1000
0
1960
1965
1970
1975
1980
1985
TOTAL CONSUMPTION
IMPORTED GAS
DAILY PRODUCTION
CALIFORNIA GAS PRODUCTION

FIGURE 17

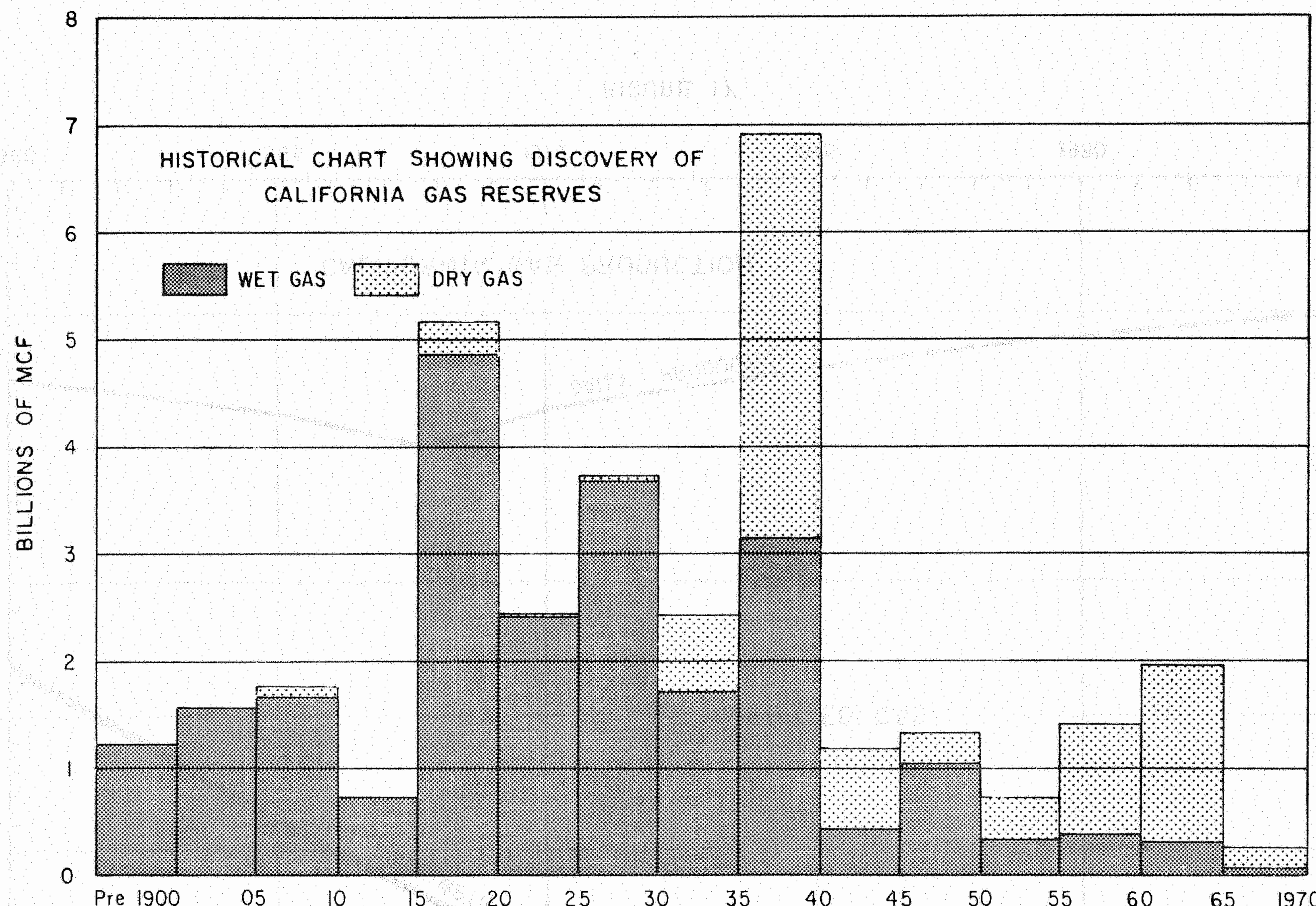

HISTORICAL CHART SHOWING DISCOVERY OF
CALIFORNIA GAS RESERVES
WET GAS
DRY GAS
BILLIONS OF MCF
0
1
2
3
4
5
6
7
8
Pre 1900
05
10
15
20
25
30
35
40
45
50
55
60
65
1970

FIGURE 18

fuels will have to be developed because the bulk of our gaseous fuels for at least the next decade will be natural gas.

Obviously there is a great need for alternate sources of supply. California presently obtains approximately 61 percent of its gas supply from the southwestern states and 17 percent from Canada. Although the amount of gas brought in from Canada is likely to increase substantially in the years ahead, it will not represent a significantly large portion of the required supply. Pacific Gas Transmission, the utility which brings Canadian gas to California, was recently denied authority to import an additional 200,000 Mcf. per day from Canada by the Canadian Natural Energy Board. It is anticipated that Pacific Gas Transmission will renew its import request as soon as sufficient reserves are available to meet present import criteria, but nevertheless the shortcomings of imports still arise. To help bolster our reserves, several California gas utilities are carrying on exploration and development ventures in Canada, Alaska, and the Rocky Mountain states. Recently these utilities have begun a program to aid in financing California gas ventures. Also, Pacific Gas Transmission is a member of Gas Arctic, which is a study group analyzing prospective pipeline routes from the Arctic area to the United States. Such participation should insure the consideration of California needs in all pipeline routing studies. As noted, imported gas is presently brought to California markets via pipeline. However, it is possible to convert natural gas to liquid form by lowering its temperature to -260° Farenheit. In this form it can be transported by specially built tankers from foreign sources. However, the high cost of these special tankers and other handling and liquification facilities makes this gas several times more expensive than pipeline gas. Thus the delivery costs to our markets would be considerably higher than the cost of domestic gas. Here again, as with imported oil, we are confronted with the problems of balance of payments, governmental instability, and unreliability from a foreign source. Nevertheless, some pilot projects have been started.

There are two locations in Alaska--Prudhoe Bay and Cook Inlet--that are possible sources of liquid natural gas (LNG). The gas may be available from Cook Inlet by 1975 if contracts can be obtained. The minimum project would be for 180,000 Mcf. per day using 120,000 cubic meter ships. The delivered price is unknown at this time because the cost of the gas at the source is unknown. LNG from Australia is being considered. The recent gas discoveries offshore in northwest Australia are likely to become available for export. The chances are now remote, however, for the central Australian Project because this gas will most likely be used in Australia. Indonesia is a possible source, but at this time little is known of the project except that Pacific Lighting Company has a letter of intent with the government-owned company concerning gas discoveries in that country. An agreement with Russia to sell LNG to the United States by 1980 seems likely as of this writing. The proposal, involving about $46 billion, will deliver gas to both the East and West Coasts. A 56-inch pipeline carrying about two million Mcf. per day would be built from Yakutsk in central Siberia to Vladivostok. At this point the gas would be liquefied for shipment to the West Coast. Cost to California consumers has been variously estimated between $1.40 - $2.00 per Mcf. Also, Algerian LNG will probably be available on the Gulf Coast of Texas in 1977. The cost of this supply would be $1.20 per Mcf. at the Gulf Coast, which would mean approximately $1.50 per Mcf. in California as compared to the approximate price of $0.35 per Mcf. currently paid for domestic gas. These are dramatic examples of rising costs of future energy supplies. Nevertheless, imports of LNG could become significant contributors to market demand by 1985.

Upon reviewing all the possible sources of gas supply--both natural and synthetic--that can be realistically made available by 1985, indications are that supply will fall very short of indicated market needs. If circumstances do not improve sufficiently to stimulate a much expanded search for North American reserves of natural gas, a significant percentage of California's market will go unsatisfied. This means that a portion of the market will have to look to other sources of primary energy.

The only direct substitutes for natural gas in California that can be utilized in the short term are oil and coal. Because of the gas shortage, it is expected that the Industrial and Electric Utilities Markets will substitute oil to meet energy requirements. For example, in 1975 it is expected that the Electric Utility Market alone will consume nearly ten times as much oil as in 1970. The Nation has a vast supply of coal, but all of the major deposits are found outside of California. Also, coal, like much of our crude oil, has a serious drawback from an air pollution standpoint because of its high sulfur content. Nevertheless, if the stage is reached where these two fuels are the primary source of the State's energy, then a trade-off may have to be made between air quality commitments and energy demand because at this point California could not have both.

Hydropower

In 1970 in California, hydropower, including imports, accounted for nine percent of the total energy supply and 36.0 percent of the Electric Utility Market; this amounts to 230 thousand barrels of equivalent oil per day.

During 1970, 104 million kwh per day of electricity was generated in California by hydropower; converted to equivalent oil, this is 177 thousand barrels per day. In addition, 31 million kwh of electricity per day generated by hydropower were imported into California from Arizona and the Pacific

Northwest. This is equivalent to 53 thousand barrels of oil per day.

Production of hydroelectricity in California is expected to increase only 8.2 percent by 1985. This slowness of growth is attributable to the scarcity of available sites and environmental restrictions. Imported hydroelectricity is expected to drop 49 percent as the Northwest consumes an increasing share of its own output. If there were unrestricted development of hydropower in California, the ultimate production would be about 164 million kwh per day, or 280 thousand barrels of equivalent oil.

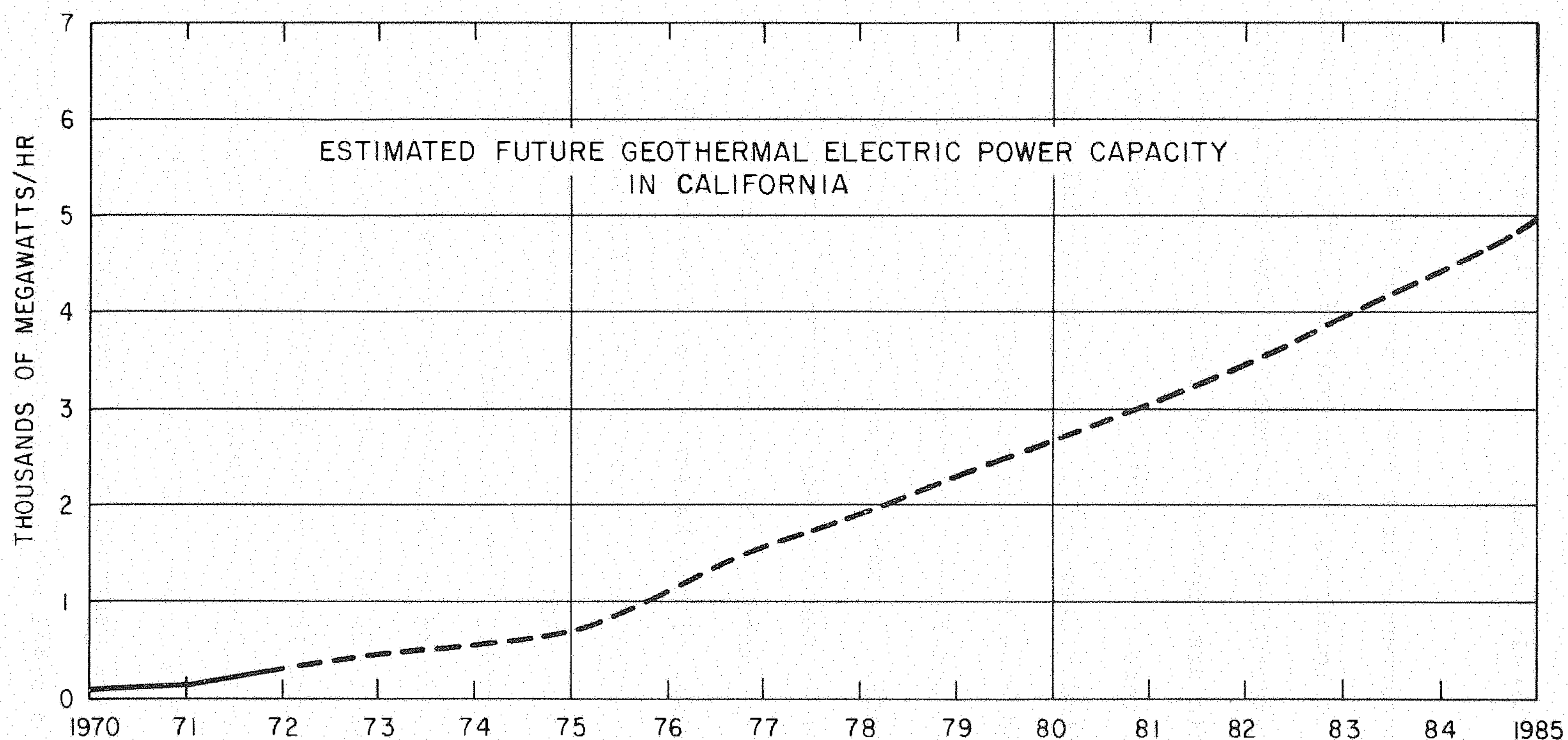
Geothermal Energy

Geothermal energy is the natural heat of the earth which can be extracted in the form of hot water and/or water vapor (steam). It is presently being used in California to generate electrical power, heat commercial and residential buildings and greenhouses, and to provide hot water for spas.

Its prime use at present is to generate electrical power as is being done at The Geysers geothermal field in Sonoma County. In 1970, geothermal energy accounted for 0.3 percent of the total energy used in the State and 1.3 percent of the Electric Utility Market. The power generation at The Geysers in 1970 was slightly above 1.4 million kwh per day, or eight thousand equivalent barrels of oil. It is estimated that by 1985 the power generation from geothermal energy, developed throughout the State, will be about 76 million kwh per day, or 130 thousand equivalent barrels.

At present the real nature of the resource is not well known; also, to what ultimate extent it can be exploited is unknown. In the one productive geothermal area, the electrical generating capacity in 1970 was 82.5 megawatts per hour; by 1985, California's total capacity, assuming technical difficulties will be overcome, might be 5,000 megawatts per hour (Figure 19). Because the State has at least 15 potential geothermal

FIGURE 19


ESTIMATED FUTURE GEOTHERMAL ELECTRIC POWER CAPACITY
IN CALIFORNIA
THOUSANDS OF MEGAWATTS/HR
0
1
2
3
4
5
6
7
1970
71
72
73
74
75
76
77
78
79
80
81
82
83
84
1985

areas (Figure 20), the energy resource could be even more significant in the future, especially in view of the rapidly rising costs of competing energy sources. However, by 1985, its contribution to the overall energy demand will likely be small, less than 3.0 percent.

Coal

Coal occurrences have been reported in 43 counties in California, but only at a few locations is the coal of sufficient quantity and quality to warrant consideration for commercial development. Most of the coal beds in California are apparently of limited extent, and few seams have been traced more than a few square miles. By comparison, coal fields in the eastern United States and in the Rocky Mountains are known to underlie hundreds and even thousands of square miles.

Records and reports of coal production in California are fragmentary and incomplete. In many places, the coal beds have not been mapped and their extent is unknown, hence recoverable reserves in the State can only be roughly estimated. The present reserve of 77.9 short tons is only 0.00005 percent of the Nation's coal reserve (Table 5).

The principal coal mines in California have been those at Mt. Diablo, Contra Costa County; Corral Hollow, Alameda County; Stone Canyon, Monterey County; Alberhill, Riverside County; and Ione, Amador County (Figure 20).

As coal found in California is generally of lignite or subbituminous rank, it has a low heating value, and generally makes poor fuel compared with coal mined in the Rocky Mountains and the eastern United States. California coal does not yield coke that is suitable for use in steel smelting. This is attributable to the high ash and sulfur content of the coal and to the weakness of the resulting coke. Coking coal for California's steel smelters is brought into the State, mostly from Utah, Colorado, New Mexico, and Oklahoma. This amounts to 17 thousand barrels

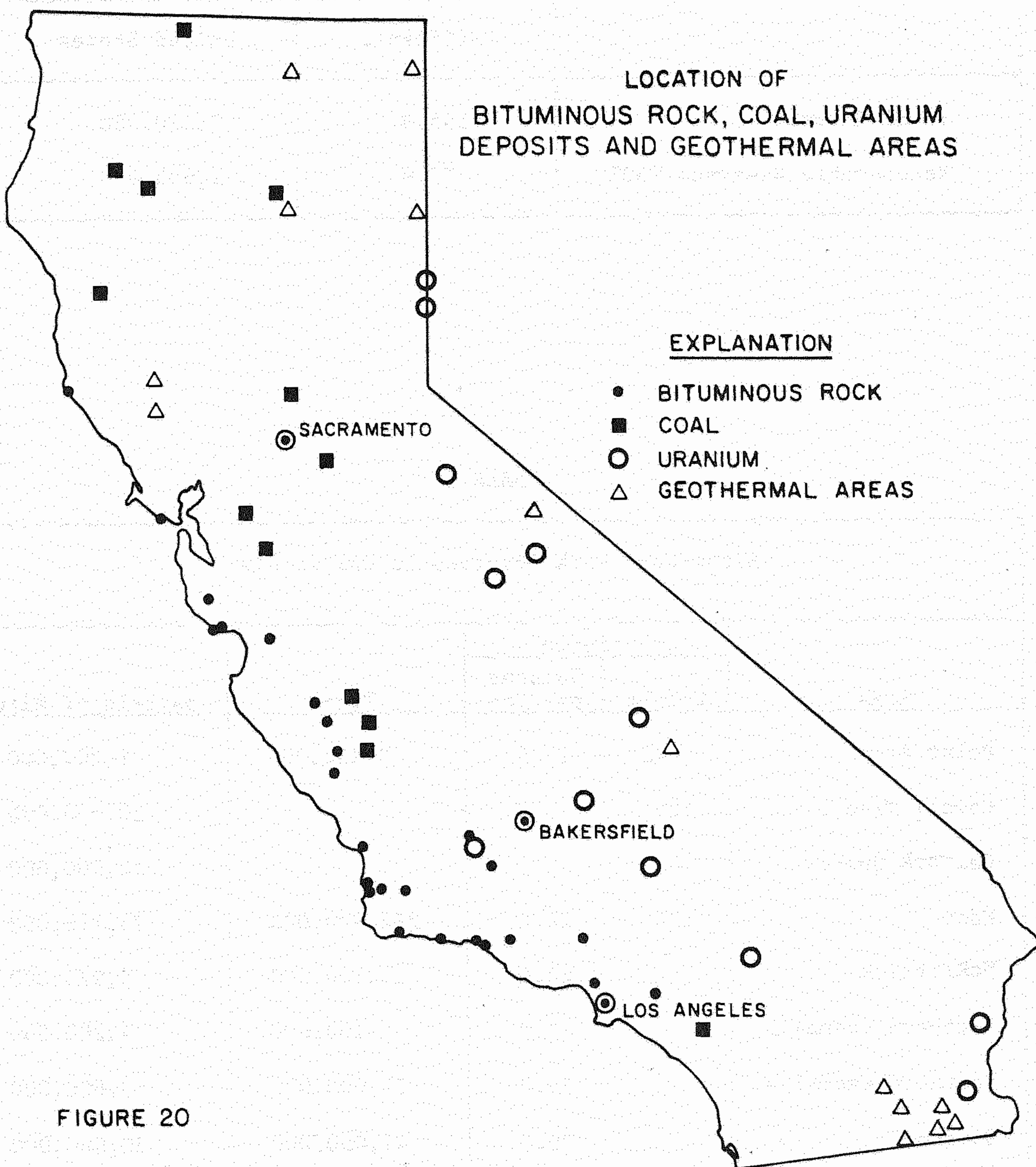


FIGURE 20

SOURCE CALIFORNIA DIV. MINES AND GEOLOGY
AND DIV. OIL AND GAS

TABLE 5

Coal Reserves in California and United States (Millions of Short Tons)		
	California	United States
Total Reserves	155.9	3,210,060
Recoverable Reserves @50%	77.9	1,605,030

TABLE 6

Bituminous Rock Reserves in California

Area	Bitumen		Tons	Barrels of Bitumen
	Weight	Gallons per ton		
Point Arena	6½%	15.6	3,232,000	1,207,000
Cowell Mine	12%			10,000,000
Calrock Quarry	10%			10,000,000
Edna	11%	26.0	282,880,000	175,116,000
McKittrick		24.0	12,100,000	6,925,000
Northern Casmalia		42.0	100,000	4,200,000
Southern Casmalia		30.0	75,000,000	53,600,000
Sisquoc		30.0	41,000,000	30,000,000
Total Reserves				291,048,000

per day of equivalent oil. Additional coal, equivalent to 15 thousand barrels of oil per day, is burned outside the State to generate electricity for California consumption.

Nuclear Fuel

Uranium combines with other elements to form a large variety of minerals. Uraninite and pitchblende are the most common of primary uranium minerals and generally occur in veins of hydrothermal origin.

Most of the uranium mined in the United States is obtained from secondary uranium minerals in sedimentary deposits in the states of New Mexico, Utah, Texas, Wyoming, and Colorado.

The first uranium ore marketed from California was shipped from the Thum Bum claim near Big Bear Lake, San Bernardino County, in the early summer of 1954. Also, in 1954 a railroad carload of uranium ore was shipped from the Miracle Mine in Kern River Canyon, Kern County. Since then about 9,000 tons of ore has been shipped from 17 different properties in the State, and the uranium contained in this ore placed California twelfth in rank among uranium-producing states.

Uranium ores have been mined in California from several different kinds of deposits in widely separated parts of the State. Nearly all the deposits are in the Sierra Nevada, Great Basin, and Mojave physiographic provinces or parts of adjacent provinces (Figure 20). However, since only about 10,000 short tons of uranium ore have been shipped from California deposits in the past 18 years, it may be safe to infer that a similar quantity of ore may be shipped in the next 20 years.

Nuclear reactors for power generation provide a heat source for making steam to drive conventional turbines. Although there have been great improvements in design, the thermal efficiency of nuclear-fired steam electric plants is about 30 percent, or roughly 10 percent less efficient than a modern fossil fuel-fired plant.

The current reactors consume more than twice the quantities of fissionable materials as they produce. The breeder reactor, however, will produce more material than it consumes. Further, the breeder is more efficient than the conventional reactor, thus producing less heat loss and radioactive waste. Breeder reactors are still in the development stages, but a full-scale plant is planned for 1980.

Uranium is the principal fuel used in the nuclear generation of electric power. Currently all this fuel is imported from other states. In 1970, it supplied 0.7 percent of the total energy requirements of the State and 3.0 percent of the Electric Utility Market. By 1985 nuclear power is expected to increase greatly and to furnish 13 percent of the total energy demand and 40 percent of the Electric Utility Market.

Because nuclear fuels are primarily used only in the generation of electricity, their use is limited. A complete substitution of nuclear fuel for oil and gas would satisfy only 25 percent of the total energy demand in 1985.

Synthetic Fuels

1. Oil shale

There are several alternate methods of obtaining petroleum supplies. One technique is the extraction of oil from oil shale. Actually the term "oil shale" commonly refers to rocks that contain a carbon compound known as kerogen, which is not petroleum, but which can be processed to yield petroleum products. The oil shale resources of the United States have enormous potential as a future source of petroleum. Large areas of the United States are known to contain oil shale deposits, but those areas in Colorado, Utah, and Wyoming that contain the oil shale-rich sedimentary rocks of the Green River formation possess the greatest promise for shale oil production in the future. Recoverable reserves from high-grade deposits have been estimated to be in excess of 80.0 billion barrels. The less accessible lower-grade deposits have a potential reserve of over 1.0 trillion barrels.

Some 72 percent of the land containing commercial quantities of oil shale is owned and managed by the Federal Government. To stimulate development, the U. S. Department of the Interior has proposed a plan of competitive bidding on selected tracts of oil shale land in accordance with requirements and recommendations of the Mining and Minerals Policy Act of 1970 and the Public Land Review Commission. Although it is too early to appraise the extent and nature of the interest by private industry in obtaining and developing oil shale leases, it is possible that, with adequate economic incentive, such as a sharp increase in the price of crude oil, the production of shale oil could reach as much as 900 thousand barrels a day by 1985.

More importantly, a basis would be laid for greater shale oil production near the end of the century when it will be urgently needed. Again, it must be noted that California has no significant deposits of oil shale.

2. Bituminous rock

Another source of petroleum is that extracted from bituminous rock (tar and asphaltic sands). These sands have been recognized for many years as a potential source of synthetic crude oil. There are numerous sand occurrences throughout the world, including several in the United States. The largest known domestic deposits are in Utah with lesser deposits in New Mexico, Kentucky, and California.

The world's largest deposit is the Athabasca tar sands in Alberta, Canada. The Great Canadian Oil Sands plant, with a capacity of 45,000 barrels a day, was placed in operation there in 1967. This marked the first large-scale recovery from tar sands. Initial operating difficulties were encountered, but improvements have been made in all phases of the operation.

In California extensive outcrops of bituminous rocks occur in several counties (Figure 20). Several areas have been extensively mined for quarry materials. Large deposits in San Luis Obispo and Santa Barbara counties have been investigated for commercial oil mining possibilities, but so far mining has not been economic. One tar sand accumulation in Santa Barbara County is operating commercially to produce lightweight concrete aggregate and pozzolan by burning oil-impregnated rock. The estimated oil reserve recoverable from tar sands by mining exceeds 290 million barrels (Table 6). The largest single reserve is over 175 million barrels at Edna in San Luis Obispo County. However, the mining operation involved in tar sand recovery presents serious environmental problems, especially in California.

3. Coal conversion

A third source for obtaining synthetic oil and gas is from coal. As noted before, the coal reserves of the Nation are by far its largest fossil fuel energy source. However, California's coal resources are quite small. Synthetic oil and gas derived from coal can be refined into a complete range of normal petroleum products. Pilot projects are now in operation, but several years more work will be required before the processes are commercially satisfactory.

The interest in making synthetic pipeline gas from coal has grown rapidly in the last few years. Coal can currently be converted to pipeline gas, although it is of somewhat lower Btu value. Coal-based gas contains about 915 Btu's per cubic foot compared to approximately 1,030 Btu's per cubic foot for natural gas. Two projects that can affect California are being contemplated, one by El Paso and a second by the Pacific Lighting Group and Texas-Eastern. Both plants will have an initial capacity of 250 thousand Mcf. per day in about 1977. The contemplated total capacity of each is 750 thousand Mcf. per day available after 1981. The cost of either of these supplies is approximately $1.00 per Mcf. over the 25-year plant life at the plant outlet. The El Paso project has an initial price of $1.20 per Mcf. However, new techniques and plant design will probably lower this price in the future.

These processes are all relatively expensive and moreover, approximately one-third of the energy content of the coal is lost in the gasification process. There are also problems of an environmental nature concerning the mining and plant operations. All of these factors, of course, add to the price of synthetic gas.

El Paso is also contemplating a gasification plant on the Gulf Coast using naphtha or condensate (petroleum products) for feedstock with a capacity of 1.25 million Mcf. per day. Gas from this plant would cost approximately $1.25 per Mcf. at the plant outlet and would be available by approximately 1977. There has also been discussion by Pacific Lighting Company to manufacture synthetic gas in the Southern California area if the projects mentioned above do not provide gas soon enough or do not come to fruition. No quantities or price data is available for this source.

4. Solid waste conversion

In 1967, about 72 million tons of solid wastes were produced in California. By the year 2000, an estimated 125 million tons of solid wastes will be generated annually by domestic, commercial, industrial, and agricultural activities.

Solid waste is grouped into three major categories: municipal (residential garbage, commercial and street refuse, rubbish, etc.), industrial (food, lumber, chemical, petroleum process waste), and agricultural (manure, fruit, nut, field, and row crop waste).

Interpolation for 1973 indicates the total anticipated quantity for that year is 77 million tons; the respective anticipated quantities of solid waste production for agriculture, municipal, and industry in 1973 are 39 million tons, 26 million tons, and 12 million tons respectively.

The U. S. Bureau of Mines is engaged in an extensive research program directed toward the recovery of energy fuels from solid waste. One program involves the recovery of oil from organic wastes. A yield of about two barrels of low-sulfur oil per ton of dry organic waste was attained in laboratory studies in 1970. This is suitable fuel for electric power plants.

In 1971 experiments, agricultural wastes, wood, lignin, and manure were successfully converted to oil. The oil can be used as fuel directly or can be converted to gasoline and diesel fuels. More work on the process will be required to determine the optimum conditions of temperature, pressure, water content of the charge, and carbon monoxide consumption, which contain the key to low cost of oil recovery.

Another program involves the recovery of oil from scrap tires. Scrap tires are shredded or cut into large pieces and placed in an electric furnace connected with condensers, scrubbers, and metering and sampling devices. Solid, liquid, and gaseous products are recovered. This method of treating tires was shown to be technically feasible with the production of potentially valuable products. No cost figures were reported for this pilot study.

A research and development company is presently operating a small pilot plant that converts solid waste to oil. The company has contracted with the County of San Diego (supported by an EPA grant) to build and put in operation by November 1974 a small-scale plant in the City of Escondido. This plant will have a capacity of 200 tons of as-received[1/] municipal solid waste per day. In addition to producing an estimated one barrel of oil per ton of waste, the plant will recover 140 pounds of ferrous metal, 120 pounds of clean glass, and 160 pounds of residual char. The char has a reported fuel value of 9,000 Btu's per pound. The company reports that a plant with a capacity of 500 tons of solid waste per day would be competitive with most existing integrated (i.e., collection, trucking, and cut and fill disposal) solid waste land-fill operations of comparable size.

In 1967, the total solid waste production in California was 72 million tons. Assuming that only 50 percent of the solid waste produced reaches disposal sites in significant volumes and that the disposal site will eventually be replaced by treatment plants, and that many new treatment plants will be built at appropriate localities throughout the State, then these plants would handle approximately

1/ Based on the following assumed content: 50 percent organic waste, 25 percent nonorganic waste, and 25 percent water.

100 thousand tons of solid waste per day and would produce oil on a one barrel for one ton as-received total waste basis. Thus, if all phases of these operations prove successful, it would be possible to produce 100 thousand barrels of oil per day from solid wastes, or about one-third of the present daily oil imports into California.

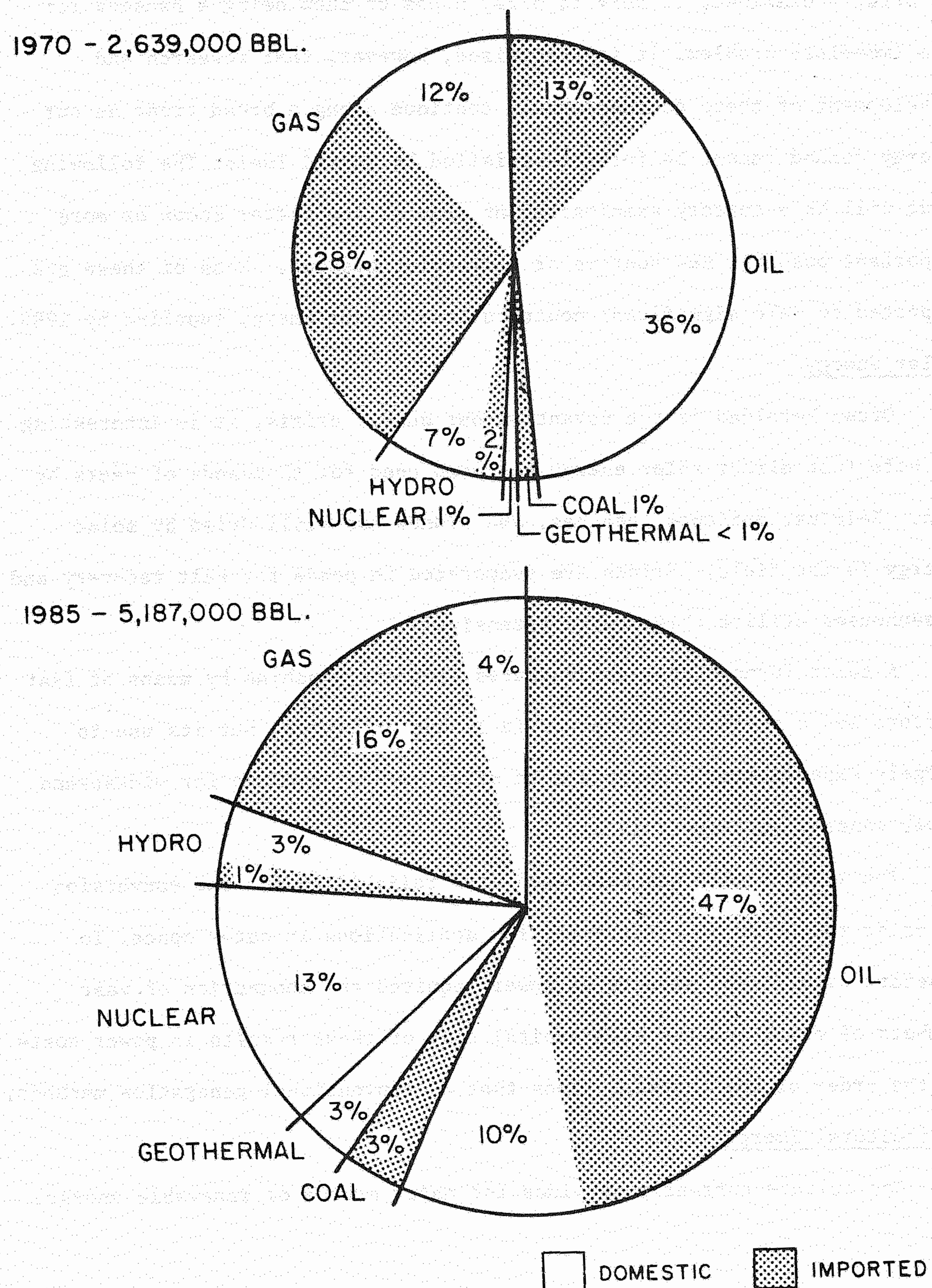
Basic Energy Supplies Together

California has no significant supplies of coal or nuclear fuel, yet electrical energy from these two sources is expected to increase substantially by 1985. In the case of coal, it will be burned outside of California in conventional steam electric plants and the electricity will be transmitted to California consumers. Nuclear fuel, however, will be imported and converted to electricity in California plants. Geothermal resources may develop into a significant supply of energy within the next several decades, but the quantity is highly speculative at present. Because new sites for dams are limited, hydropower will provide a lesser share of the total market in the future. Oil and natural gas will still supply the bulk of our energy requirements through 1985. The level of gas consumption is not expected to change due to the limited availability. Oil consumption will increase sharply and as our domestic production declines, imports will grow from 337 thousand barrels per day to about 2.5 million barrels per day.

Figure 21 shows the proportion of the total energy market that each fuel occupied in 1970 and the proportion that they are expected to occupy in 1985, together with the probable relative level of domestic and imported availability.

FIGURE 21

CALIFORNIA
BASIC ENERGY SUPPLIES



NEW SUPPLIES OF ENERGY

Although fossil fuels, particularly oil, will continue to be our dominant energy source through 1985, the exotic energy sources need to be briefly examined, if only to allay hopes of them being a panacea for the immediate problem. It is recognized, however, that research and development of these sources should continue along a broad front as our energy demand cannot be forever satisfied by fossil fuels. The following text will be a cursory examination of some of the better known or more important possible new sources or conversion systems. None of these are expected to make significant contributions to our energy supplies by 1985.

Solar Energy

Often heralded as the savant of our energy crisis, it is interesting to note that direct solar energy has been used for thousands of years by man. Raisins, apricots, peaches, and prunes are still dried by solar energy in the field. Brines are evaporated in ponds for salt recovery and greenhouses utilize this source extensively.

A solar furnace that concentrates incident sunshine by means of flat mirrors and a parabolic reflector is in use in France, but its use is largely experimental and appears to offer no real promise for widespread power generation (Weaver 1972).

The silicon cell has been used with reliability for the conversion of solar radiation to electricity for applications in outer space. To generate significant amounts of power requires the connection of vast numbers of cells and the high capital cost of these results in power costs on the order of one thousand times that of conventional generation methods.

Agricultural Energy

Agriculture currently provides the major source of renewable energy.

Forests and cultivated lands can be used repeatedly for the production of energy. Some by-products of agriculture, including forests, are now used as energy sources, but although significant for their specific purpose, they are insignificant in the total energy picture. Some lumber mills utilize wood waste to fire steam boilers, and fruit seeds and nut shells are used to make charcoal briquets.

Currently some alcohol is produced by fermenting grains, but the cultivation of crops strictly for the production of energy has been given little consideration. Cereal grains could be raised exclusively for their value as carbohydrates for fermentation, and with hybridization of new varieties for this single purpose, yields of usable carbohydrates could undoubtedly be increased.

It has been estimated (NPC 1971) that on a national basis about 18 billion gallons of alcohol could be produced from grain not needed for food. Taking into account that alcohol has a heating value of 65 percent of that of gasoline, this would replace about 14 percent of our national consumption of gasoline.

Tidal Energy

Three major problems concerned with the development of tidal energy are that there is negligible potential in California, capital costs are high, and there are adverse ecological effects from damming an entire bay or estuary. The tidal range (height between high and low tide) varies from five feet off Southern California to about 7.5 feet off the coast of Washington. Several areas in Northeastern United States, Alaska, and Canada do have ranges in excess of 20 feet, and therefore, have some potential.

The concept of using the rise and fall of the tides to produce power has long interested the inventor. The only practical method demonstrated so far is based on the use of tidal basins separated from the sea by dams and of hydraulic turbines through which the water passes between the basin and sea.

The only large-scale plant of this kind is on the Rance River in France; the output is 240 thousand kwh (Weaver 1972).

Hydrogen

The possibility of utilizing hydrogen as a replacement fuel for natural gas is a fascinating concept. Hydrogen burns hotly and the only emission is water vapor. It can be transported by the same systems that transport natural gas. At present there is no commercial method of making hydrogen gas for widespread use. It can be made from petroleum, but to be a substitute fuel, it would probably be made by separating water into hydrogen and oxygen by electrolysis. The electricity could be generated by nuclear or wind power stations located offshore and thus the hydrogen would be made on site and piped ashore where it would be used as a substitute for natural gas, including the generation of electricity by fuel cells.

Energy Conversion Systems

1. Fuel cells

The fuel cell is a chemical-to-electrical-energy-conversion device in which complete conversion of energy is theoretically possible. Natural gas, alcohols, gasified coal, or other materials containing large amounts of hydrogen can be reformed to hydrogen gas, and this is then used with oxygen to produce electricity. In practice, the conversion efficiency is between 40 and 50 percent which is about 10 percent better than fossil fuel-fired plants. Another significant advantage is that there are fewer environmental deficiencies.

In 1967 a nationwide group of gas companies, together with

Pratt and Whitney Aircraft, started a nine-year pilot program to explore, research, develop, and test natural gas fuel cells for on-site electric power generation. To date, $50 million has been invested and 30 units have been installed in various localities throughout the Nation. Should this program prove successful, the power plant that could be brought to market would be smaller, lighter, and capable of years of unattended operation. However, it is not likely that fuel cells will have a significant effect on California's total energy market before 1985.

2. <u>Total energy systems</u>

In a total energy system, waste heat from the electrical generating system is used to supply other energy needs in an establishment. Gas and diesel engines or gas turbines are the usual prime movers. The economic appeal of these systems is their high fuel efficiency (up to 70 percent) and low energy costs relative to network-electricity if cheap fuels are available. With the increasingly less favorable economics for natural gas beyond 1975, it is not expected that total energy systems will have a significant effect on the energy picture during the forecast period of this report.

3. <u>Magnetohydrodynamics</u> (MHD)

The energy contained in a hot electrical-conducting gas is converted directly into electric power when the charged particles of gas cut through the field of an external magnet.

The promise of MHD is that it is a simple conversion device that offers high thermal efficiency (about 60 percent) and will work well with the combustion of gas or coal, our most abundant fossil fuel. MHD can also be used as a "topping" device (using hot exhaust gas) in conjunction with conventional gas turbines.

There are still some technical and engineering problems to be worked out before MHD will be a significant power source. It is probable that MHD peaking plants will be functioning before 1985.

4. Nuclear fusion

The nuclei of the lightest elements can be made to fuse to form heavier nuclei and in the process release enormous quantities of thermal energy. Controlled thermonuclear fusion offers the possibility of direct conversion of this thermal energy into electricity and an almost infinite source of energy.

Deuterium, an isotope of hydrogen, is the essential fuel for fusion. Deuterium can be extracted readily at relatively low costs from water which contains one atom of deuterium for each 6,500 atoms of ordinary hydrogen. The world's oceans represent a virtually inexhaustible potential source of fuel. Thus, the development of controlled fusion would provide an unlimited energy source.

However, technological and economic problems facing the successful development of fusion are so great at this time that fusion as a practical energy source will not be available by 1985.

With sufficient support, a demonstration fusion power system might be built by the end of this century. However, there is a big difference between establishing a scientific principle and translating it into a commercially successful industry. In this case, the difference amounts to years of effort and billions of dollars of investment, assuming it can be done at all (U. S. Department of the Interior, 1972).

CONSERVATION OF ENERGY

There are two principal ways to conserve energy: (1) by increasing efficiency of conversion, and (2) by restricting demand. In the introduction it was pointed out that there is a strong correlation between energy consumption and gross national product. If steps to restrict energy consumption are based on measures which will make energy use too costly for certain segments of society, then there is a real risk that the growth of GNP will suffer. A corollary of this would be an increase in the balance of payments deficit brought about by the competitive disadvantage that our goods would face against goods manufactured abroad with cheap energy.

The following discussion will only briefly touch on some of the better known or popularly credited methods of energy conservation. This important subject could easily be expanded into a separate report.

Methods to Increase Efficiency

In California less than half of our energy consumption does useful work; the remainder is waste, mostly in the form of heat. This amounts to about 1.3 million barrels per day of equivalent oil.

Conversion of energy resources to heat for process steam and space heating are highly efficient, nearly 90 percent. Conversion of falling water to electricity is also highly efficient, about 85 percent. But, the internal combustion engine is only 25 percent efficient, the incandescent lamp less than 5 percent, Wankel engine 17 percent, and nuclear electric 30 percent. Although some electrical devices, such as motors and transformers, are extremely efficient, the basic conversion system of energy resources which renders them operable is only about 33 percent efficient.

A quantum jump in efficiency of steam electric power plants was made between 1900 and 1970 when it rose from four percent to 33 percent.

Railroad locomotives made like increases when they switched to diesel electric (Summers 1971).

Industry is constantly searching for more efficient energy conversion systems; the search will intensify as energy becomes more expensive. A new system of generating electricity from coal has been devised which will achieve 51.1 percent efficiency compared to the best 39.5 percent for conventional model plants. This increase effectively adds 11.6 percent to our coal reserves.

It is apparent, therefore, that improved efficiency in conversion systems holds excellent promise for increasing the longevity of our resources and reducing pollution.

Restricting Energy Demand

Much publicity has been given to restricting demand as an energy conservation means. A tax on horsepower, a halt to new electrical generating plants, a restriction on development of resources, a prohibition on advertising by energy suppliers--these have all been proposed. To some extent these are now in effect; however, no measurable impact has yet been documented.

POSTSCRIPT

The findings of this report lead to the following questions:

1. How can we stimulate domestic development of energy supplies?
2. Can the State accommodate vastly increased tanker traffic including providing deep water ports and attendant facilities?
3. Can environmental controls be more flexible?
4. Can incentives be given for high efficiency in use of fuel?
5. How dependent can the State afford to become on foreign oil and gas?
6. How can the State provide for increased consumption of energy and yet preserve the environment and improve the quality of life?

It is obvious that answers to these questions will not be easily attainable. An in-depth study or studies need to be made which will bring the exceedingly complex interrelationships among demand, supply, environmental quality, esthetic desirability, and government policy into focus.

GLOSSARY

Asphalt - A brown to black solid or semisolid bituminous substance occurring in nature.

Barrel - A liquid volume measure equal to 42 U. S. gallons.

Bituminous coal - "Soft coal," coal containing between 15 and 50 percent volatile matter.

Bituminous rock - A rock containing hydrocarbons or bituminous material.

Breeder reactor - A nuclear reactor that creates more fissionable fuel than it consumes.

Btu - British thermal unit; the amount of heat needed to raise the temperature of one pound of water 1^{o} F. at or near 39.2^{o} F.; a measure of energy.

Coal gasification - The conversion of coal to a gas suitable for use as a fuel.

Condensate - Known sometimes as distillate. A heavier hydrocarbon occurring usually in gas reservoirs of great depth and high pressure.

Conversion factors -

Crude oil	5,800,000 Btu per barrel
Residual fuel oil	6,287,400 Btu per barrel
Petroleum coke	6,024,000 Btu per barrel
Bituminous coal	26,200,000 Btu per ton 4.51 Barrels per ton
Coke	24,800,000 Btu per ton 4.27 Barrels per ton
Kilowatt hour (kwh)	3,412 Btu per kwh (theoretical) 9,895 Btu per kwh (at 34.5% efficiency) .0017 Barrels per kwh
Oil shale	5,800,000 Btu per barrel of recovered oil
Wood	20,960,000 Btu per cord 3.61 Barrels per cord

Diesel oil - Fuel used for internal combustion in diesel engines; usually that fraction which distills after kerosine.

Enriched uranium - Uranium in which the amount of the fissionable isotope, uranium-235, has been increased above the 0.7 percent contained in natural uranium.

Fission - The splitting of an atomic nucleus by a subatomic particle (free neutron) to produce a large amount of energy.

Fossil fuel - Any naturally-occurring fuel of an organic nature, such as coal, crude oil, and natural gas.

Fuel cell - A device in which fuel and oxygen are combined to produce chemical energy that is converted directly into electricity.

Fuel oil - Relatively heavy refined oil used as fuel for producing heat or power.

Fusion - The formation of a heavier nucleus from two lighter ones with the attendant release of a large amount of energy.

Geothermal energy - The heat energy available in the earth's subsurface.

Gross national product (GNP) - The total market value of the goods and services produced by the nation before the deduction of depreciation charges and other allowances for capital consumption; a widely used measure of economic activity.

High-sulfur coal - Generally, coal that contains more than one percent sulfur by weight.

Hydroelectric plant - An electric power plant in which the turbine-generators are driven by falling water.

Jet fuel - Fuel meeting requirements for use in jet engines and aircraft turbine engines, generally of kerosine or naphtha base components.

Kilowatt - One thousand watts.

Kilowatt hour - The amount of energy equal to one kilowatt in one hour; equivalent to 3,412 Btu's.

Liquefied natural gas (LNG) - Natural gas that has been changed into a liquid by cooling to about -260° F., at which point it occupies about 1/600 of its gaseous volume at normal atmospheric pressure.

Liquefied petroleum gas (LPG) - Propane, butane, or mixture thereof; kept in the liquid state by pressure or refrigeration to facilitate handling.

Low-sulfur coal and oil - Generally, coal or oil that contains one percent or less of sulfur by weight.

Magnetohydrodynamic (MHD) generator - One that produces electricity by passing hot plasma through a magnetic field.

Mcf. - One thousand cubic feet.

Megawatt (MW) - One thousand kilowatts.

Megawatt-hours (MWh) - One thousand kilowatt-hours.

Naphtha - Liquid hydrocarbon fractions recovered by the distillation of crude petroleum.

Natural gas - Naturally-occurring mixtures of hydrocarbon gases and vapors, the more important of which are methane, ethane, propane, butane, pentane, and hexane.

Nuclear electric powerplant - One in which heat for raising steam is provided by fission rather than combustion of fossil fuels.

Nuclear energy - Energy produced largely in the form of heat during nuclear reactions, which, with conventional generating equipment can be transformed into electric energy.

Nuclear (atomic) fuel - Material containing fissionable materials of such composition and enrichment that when placed in a nuclear reactor will support a self-sustaining fission chain reaction and produce heat in a controlled manner for process use.

Oil shale - A sedimentary rock containing solid organic matter (kerogen) that yields substantial amounts of oil when heated to high temperatures.

Petroleum - A naturally-occurring material (gaseous, liquid, or solid) composed mainly of chemical compounds of carbon and hydrogen.

Quadrillion Btu - 10^{15} (thousand million million) Btu's; equal to the heat value of 965 billion cubic feet of gas, 175 million barrels of oil, or 38 million tons of coal.

Reserves - The amount of a mineral expected to be recovered by present-day techniques and under present economic conditions.

Residual fuel oil - Topped crude petroleum or viscous residuum obtained in refinery operation. (Am. Petroleum Inst. Glossary).

Resources - The estimated total quantity of a mineral in the ground; includes prospective undiscovered reserves.

Secondary recovery - Any method of augmenting the natural energy of a petroleum reservoir to increase production.

Short ton - A unit of weight that equals 20 short hundredweights or 2,000 avoirdupois pounds. Used chiefly in the United States, in Canada, and in the Republic of South Africa. (USBM, Dictionary of mining, mineral, and related terms).

Solar energy - Radiation energy from the sun falling upon the earth's surface.

Steam-electric plant - A plant in which the prime movers (turbines) connected to the generators are driven by steam.

Subbituminous coal - Coal of rank intermediate between lignite and bituminous; weathering and nonagglomerating coal having calorific values in the range 8,300 = 13,000 Btu, calculated on a moist, mineral-matter-free basis. (American Society for Testing Materials, D338-38).

Synthetic liquid fuel - Liquid hydrocarbon material produced from solid carbonaceous material, such as oil shale.

Synthetic natural gas (SNG) - Gas produced from conversion of some solid carbonaceous material, such as coal.

Tar sand - Any sedimentary rock that contains bitumen or other heavy petroleum material that cannot be recovered by conventional petroleum recovery methods.

Thermal plant - A generating plant which uses heat to produce electricity. Such plants may burn coal, gas, oil, or use nuclear energy to produce thermal energy.

Watt - The rate of energy transfer equivalent to one ampere under a pressure of one volt at unity power factor.

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