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California Energy Flow in 1985

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ABSTRACT

Energy use in California in 1985 increased 4.8% as compared to a 1.4% increase in the nation as a whole. A part of the increase can be traced to increase in population which is estimated to have been 2%. Total energy consumption in the state reached the level of the peak year of 1979. The increase is associated with greater use of natural gas in all end-use sectors, which resulted in increased reliance on imported gas from Canada. The transportation end-use sector, which accounts for 37% of all consumed energy in the state, fell slightly from 1984 levels due to lower sales of bunkering fuels; the drop more than compensated for an increased consumption of motor gasoline and aviation fuels.

California crude oil production was at an all time high due to expansion of steam and flooding; however production at the Naval Petroleum Reserve No. 1 (Elk Hills) declined for the fourth year. The nuclear contribution to electrical power production increased as the Diablo nuclear plant came to full power. Imported power from out-of-state hydroelectric and coal-fired plants is the largest source of power to the state. Of almost equal importance are California hydroelectric installations and generation using natural gas as a fuel. Cogeneration and self generation in the state began to pose problems for both the utilities and regulators as the growth of both has been so rapid as to complicate planning and rate making. Together these two contributions to the electrical sector equate to about 4.5% of transmitted power. Alternate energy forms such as geothermal and windpower continued to grow; however it is uncertain whether the growth in windpower will continue as federal tax incentives expired at the end of the year. In addition environmental objections to wind installations began to surface in the southern part of the state.

INTRODUCTION

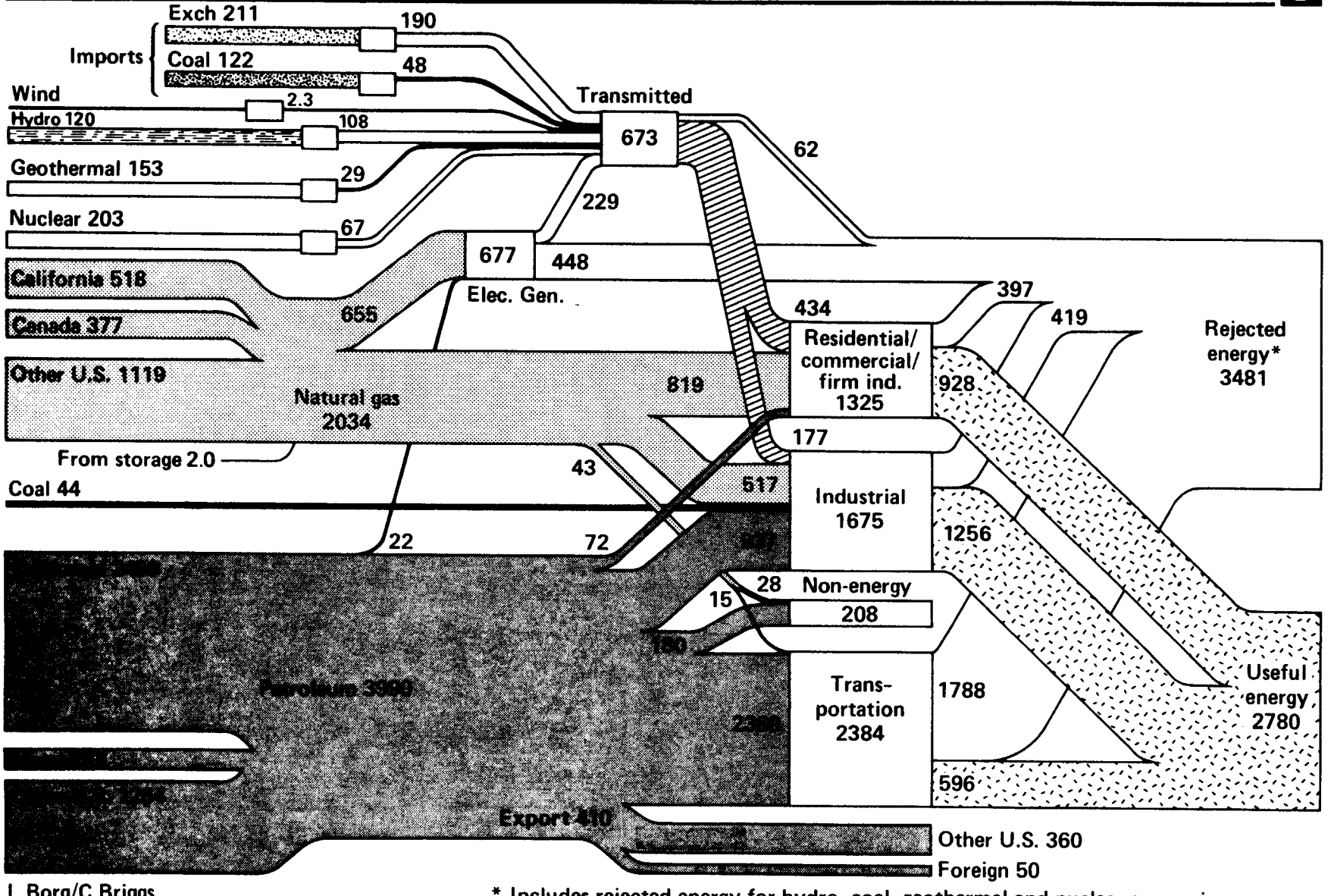
For the past ten years energy flow diagrams for the State of California have been prepared from available data by members of the Lawrence Livermore National Laboratory[1-6]. They have proven to be useful tools in graphically expressing energy supply and use in the State as well as illustrating the difference between particular years and between the State and the US as a whole.

As far as is possible similar data sources have been used to prepare the diagrams from year to year and identical assumptions[2] concerning conversion efficiences have been made in order to minimize inconsistencies in the data and analyses. Sources of data used in this report are given in Appendix A and B; unavoidably the sources used over the 1976-1985 period have varied as some data bases are no longer available. In addition, we continue to see differences in specific data reported by different agencies for a given year. In particular, reported data on supply and usage in industrial/commercial/firm industrial/residential end-use categories have shown variability amongst the data gathering agencies, which bars detailed comparisons from year to year. Nonetheless, taken overall some generalizations can be made concerning gross trends and changes.

CALIFORNIA'S ENERGY FLOW IN 1985 COMPARED TO 1984

California's energy use rose in 1985 to a level commensurate with that recorded in the peak year of 1979. The increase over 1984 (compare Figure 1 and 2) can be traced in large part to increased use of natural gas primarily in the residential, commercial and firm industrial end-use sectors

CALIFORNIA ENERGY FLOW -1985
TOTAL CONSUMPTION 6500 X 10^{12} Btu



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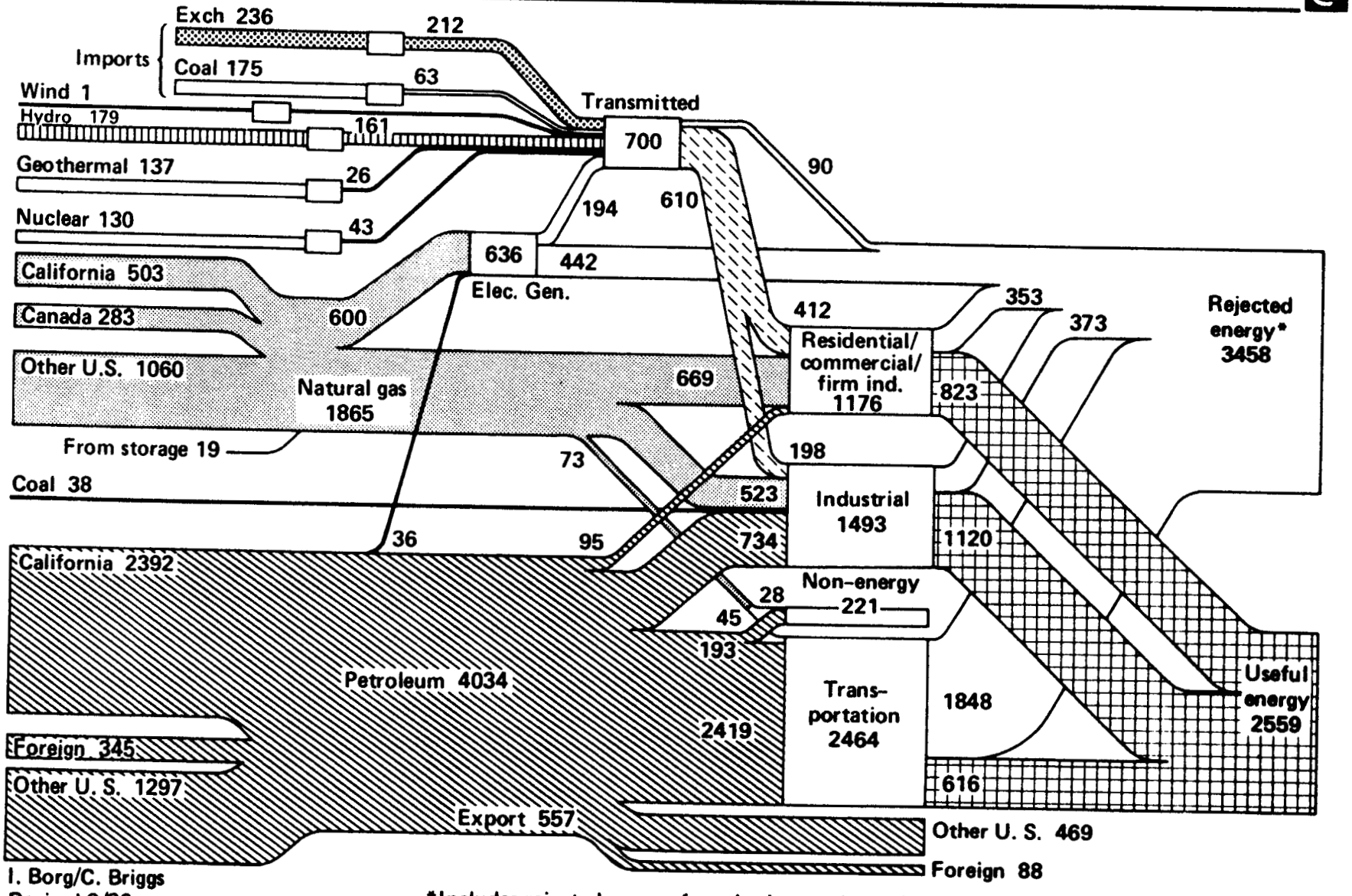
* Includes rejected energy for hydro, coal, geothermal and nuclear conversions

Figure 1

CALIFORNIA ENERGY FLOW – 1984
TOTAL CONSUMPTION 6200 X 10^{12} Btu



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*Includes rejected energy from hydro, coal, geothermal and nuclear conversions

Figure 2

despite a mild winter (Table 1) Overall oil use remained at 1984 levels as did consumption in the transportation end-use sector. Gasoline and aviation

Table 1

WEATHER COMPARISON

1958 - 1985
ANNUAL HEATING DEGREE DAYS

	San Francisco Federal Office Building	Los Angeles Civic Center	San Diego Lindbergh Field
1958	2332	849	805
1967	2978	1040	1380
1968	2942	850	1052
1969	3066	941	1137
1970	3006	941	1137
1971	3468	1424	1657
1972	3240	918	1166
1973	3161	1066	1137
1974	3182	1084	1123
1975	3313	1548	1416
1976	2665	1128	793
1977	2888	911	747
1978	2599	1208	736
1979	2545	1160	902
1980	2799	597	590
1981	2819	506	573
1982	3195	975	913
1983	2386	602	623
1984	2648*	704	713
1985	2486	921	1079
Normal 1951-80	3071	1204	1284

*CA. Mission Dolores - same historical data as for Federal Office Building

Source: Local Climatological Data for San Francisco, Los Angeles and San Diego.

fuel sales were up in 1985 by about 2%; however the increase was compensated for by a decline in sales of diesel and residual oil used for vessel bunkering (Table 2). The increase in energy use was larger than that experienced by the US in the same time frame - 4.8% versus 1.4% perhaps reflecting the estimated

Table 2

California Transportation End Use (10^{12} Btu)

	1979	1980	1981	1982	1983	1984	1985
Net gasoline	1439	1375	1384	1345	1418	1413	1445
Net aviation fuel	350	346	335	298	318	348	379
Taxable diesel fuel-public highways	161	160	166	161	168	201	207
Rail diesel	35	43	46	42	41	27	31
Net bunkering fuel	358	430	412	346	316	390	274
Military	30	32	42	36	35	40	33
Natural gas (pipeline fuel)	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	45
Total	2373	2386	2385	2228	2296	2464	2384

n.d. : not determined

2% annual increase in the state's population. The nature of California's demand and sources of supply continued to show marked variance with that of the US as a whole (Figure 3). The disparity would be even greater if California were to be excluded from the US picture, i.e. if it were compared to energy supply and demand in the other forty-nine states.

U.S. Energy Flow — 1985
Net Primary Resource Consumption 74 Quads

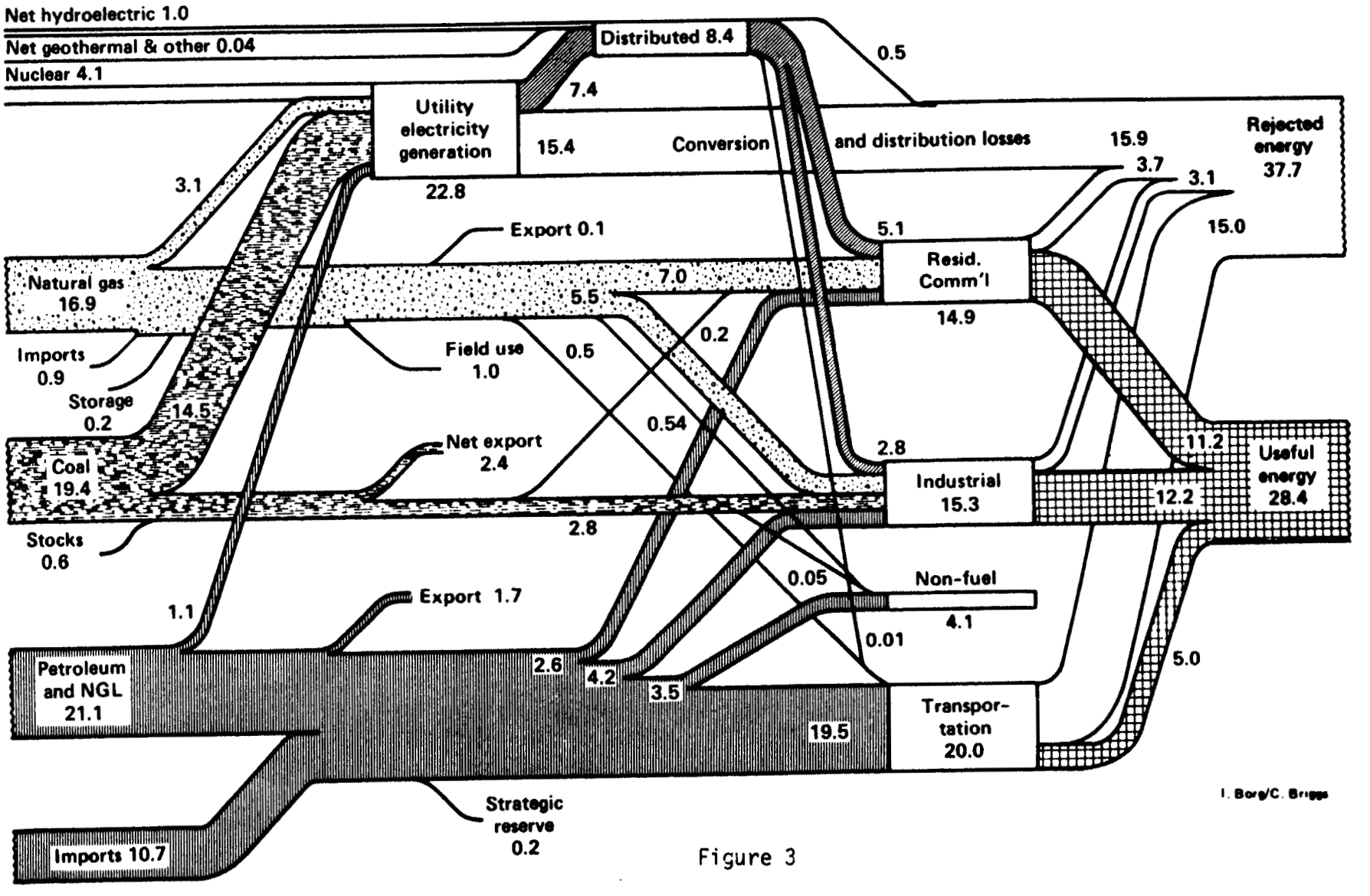

Figure 3

Noteworthy trends and changes in 1985 include:

- o A record year for California crude oil production due to increases in production from steam flooding
- o A substantial increase in the nuclear contribution to electrical generation as Diablo Canyon came to full power
- o Continued growth in the amount of cogenerated power sold to utilities and the amount of self-generated power
- o A greater reliance on imported natural gas from Canada
- o Higher demand for all types of energy in heavy industry and agriculture in the state

A historical resume of specific details of California's supply and use are shown in Table 3.

OIL PRODUCTION

California's crude oil production set a record high in 1985 primarily because of increased production in established onshore fields. California and Alaska increases accounted for the overall increase in production in the U.S. as collectively they more than compensated for declines in other producing states such as Texas. The largest increases in California occurred in the South Belridge Midway-Sunset and Kern River heavy oil fields in Kern County, which were subject to expanded enhanced oil recovery (EOR) operations, in the form of steam and hot water flooding. At year-end 55% of California's production was attributed to EOR, almost three quarters of which was steam flooding and the remainder water flooding[7]. The Kern County oil fields have been the center of numerous large cogeneration projects which have proposed to use natural gas for oil as fuel to raise the steam for flooding operations.

Table 3

Comparison of Annual Energy Use in California

(in 10^{12} Btu)

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Natural Gas	1884	1831	1724	1971	1910	2010	1893	1769	1865	2034
Crude Oil	3886	4516	4379	4587	4391	4180	3889	3883	4034	3990
California Source	1921	2027	2014	2044	2071	2230	2330	2355	2392	2459
Foreign Imports	1606	1875	940	785	591	390	266	328	345	267
Other U.S.	359	614	1425	1758	1729	1560	1293	1200	1297	1264
Domestic/Foreign Exports	630	796	598	620	557	530	562	554	557	410
Net Use	3256	3720	3781	3967	3834	3650	3327	3329	3477	3580
Electricity										
Imports and Purchases*	267	208	203	193	252	300	356	365	411	333
(Net)	(158)	(100)	(121)	(92)	(137)	(180)	(237)	(226)	(275)	(238)
Hydroelectric	94	54	144	134	164	110	191	216	179	120
Geothermal and Other	79	63	54	71	93	110	89	111	137	153
Nuclear	51	84	81	96	51	30	39	42	130	203
Gas	303	380	312	458	534	680	560	490	600	655
Oil	619	806	619	640	391	280	94	70	36	22
Total Fuel	1413	1595	1413	1592	1485	1510	1329	1294	1493	1488
Total Transmitted Energy	577	574	597	617	622	620	642	622	700	673
Residential/Commercial/										
Firm industrial	1406	1253	1321	1398	1334	1370	1225	1268	1176	1325
Industrial	1162	1248	1088	1216	1294	1400	1570	1395	1493	1675
Non-energy	222	221	239	304	298	165	158	183	221	208
Transportation	2004	2199	2438	2478	2471	2430	2265	2313	2464	2384
TOTAL ENERGY CONSUMPTION†	5700	6000	6050	6500	6400	6300	6000	5900	6200	6500

*Calculated hydroelectric power of coal before conversion to electricity. Data in parentheses are actual imported Mwh from these same sources.

† Total is not sum of above figures.

At year-end, 485 MWe capacity was installed in the oil fields, and there was at least another 1500 MWe in the proposal and approval stage.

Elk Hills field, Naval Petroleum Reserve #1, continued to be produced by operators for the U.S. Government. Its production declined for the fourth year. It has fallen from its position of first-ranked oil-producing field in the state in 1979 to fourth in 1985. It remains the top rank gas-producing field in the state, however.

NATURAL GAS SUPPLY

California's onshore and offshore gas production supplies only ten percent of the state demand. The remainder is imported from southwestern states (65%) and Canada (35%). Southwestern reserves are being depleted although gas surpluses exist locally, and a price war between southwestern and Canadian suppliers erupted in 1985. The expected shortfall in southwestern gas in the coming decades is anticipated to be made up by increased Canadian imports. State agencies have been increasingly concerned with growth in cogeneration fueled by natural gas in industrial operations and EOR projects since it acerbates an anticipated supply problem. Of special concern is the ability of the state's utilities to compete for imported gas for their residential, commercial and firm industrial customers. Three pipelines - El Dorado Interstate Transmission Co., The Mohave Pipeline Co. and the Kern River Gas Transmission Co. have applied to the Federal Energy Regulatory Commission for permits to build pipelines to carry gas to the cogeneration plants in the heavy oil fields.

ELECTRICAL POWER PRODUCTION

Source of fuels

Imports of electricity constitute the largest single source of power to the state. They consist of purchases from the Western Area Power Administration (most importantly from Hoover Dam), from the Bonneville Power Administration (Bonneville Dam) and from out-of-state coal-fired power plants that are in part owned by California utilities. Next in importance, and almost as large, is power produced from natural gas which is supplied primarily from interstate and Canadian sources. It is burned in the summer months when demand for gas for space heating is low. Oil has almost been eliminated as a fuel for electrical generation by the utilities; however it provides power for some small self generators. Hydropower from California sources is also sizable. From the standpoint of fuels hydropower is the most important resource if the combined contributions from hydroelectric plants in California and other western states are taken into account. Collectively hydropower from these sources supplies almost half of the electricity ultimately consumed by California customers. Additional contributions are made by nuclear, geothermal and wind energy.

Nuclear Power

The 36% increase in nuclear power's contribution to electricity generated within the state reflects the fact that Diablo Canyon 1 nuclear plant reached full power in May and Diablo Canyon 2 received its full power licensing in August and subsequently began low power testing. Collectively the two units (2.2 GWe) more than compensated for the shutdown of

the Rancho Seco nuclear plant (928 MWe), which had only a 25% load factor during the year. The start-up of Diablo Canyon marked the end of 17 years of nuclear controversy, one of the longest in the history of American nuclear power.

The state had six licensed power reactors at the end of 1985, and since there are none in the planning stage, it is unlikely that any more plants will come on line in the state in this century.

Hydropower

Although less than normal rain and snow reduced hydroelectric generation in the state, the principal concern in 1985 for the state's utilities was a controversy over federal relicensing rights. At the end of the year the two major utilities in the state (Pacific Gas and Electric and Southern California Edison) owned and operated 86 hydroelectric power plants and provided 85% of the state's hydro power. Many of these plants were built in the 1920's and 1930's and were paid for and maintained by the utilities, and the costs were passed onto their customers. Hydropower represents the cheapest power to produce throughout the world. Original licenses ran for about 50 years which meant that many were due to be relicensed. Relicensing of some of these plants was contested by municipal and other government operated utilities who claimed that the Federal Power Act of 1920 gave them preferred status over regulated private utilities for renewals as well as for initial development licenses. In 1980 the Federal Energy Regulatory Commission ruled for the municipal utilities and then reversed itself in 1983. Nonetheless by that time a rash of litigation and licensing challenges had been set in motion. Late in 1985 the U.S. Court of Appeals for the District of Columbia decided that a preference exists in favor of the

municipal utilities. Extension of that decision to California potentially would have cost rate payers served by the two major utilities an estimated one billion dollars in 2000[19]. In October 1986 the Electric Consumers Protection Act was passed whereby licenses were to be awarded under specific public interest criteria and insuring that the government owned utilities would not have preferential status in relicensing proceedings.

Geothermal energy

At the end of 1985 the Geysers Geothermal field in Lake County, 90 miles north of San Francisco had total electrical generating capacity of 1,718 MWe, a 329 MWe increase over 1984 (Figure 4). It is an area

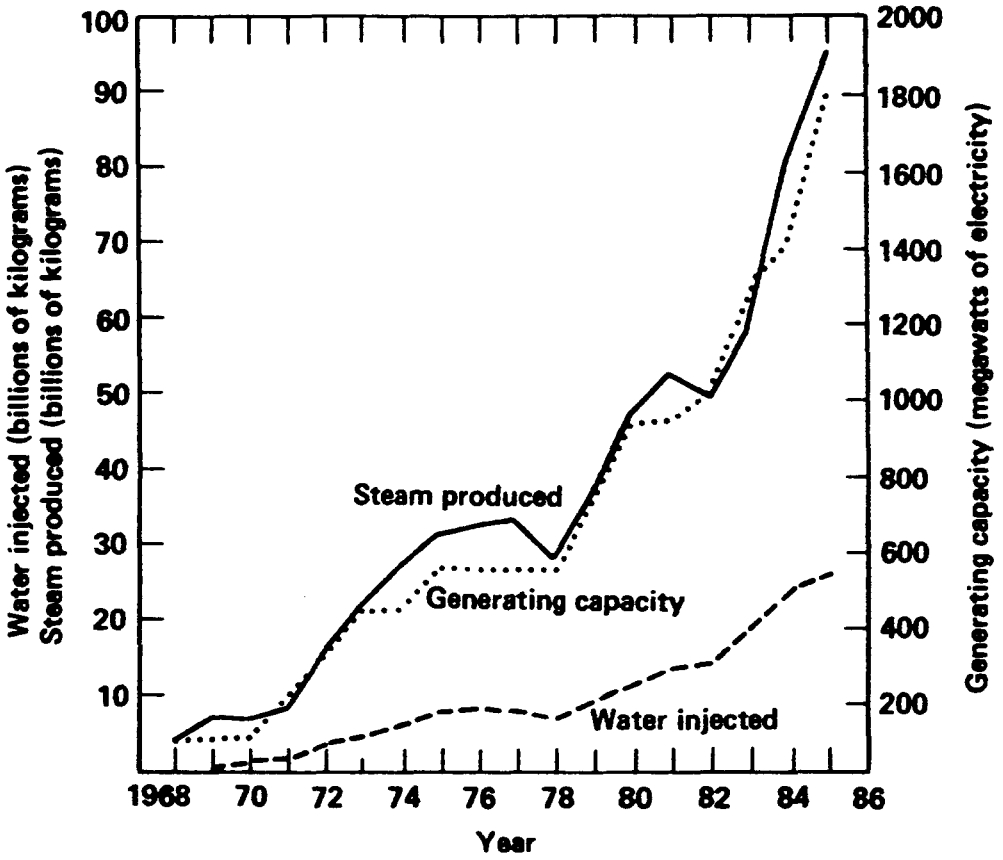

Figure 4 Development of geothermal energy in California (Ref. 7)

of active development, and 1986 should see a similar increase. For the first time geothermal power was put on line at Heber in the Imperial Valley - a 47 MWe dual-flash plant and a 45 MWe binary plant. Another plant (32 MWe) was completed at the Salton Sea by Magma Power Co. bringing the total geothermal generating power outside of the Geysers to about 150 MWe. The Coso Geothermal Resource area within the China Lake Weapon's Center in Inyo County and the East Mesa field in the Imperial Valley were being drilled and developed and should be on line shortly. By the end of 1985 the installed capacity in geothermal fields equated to 5% of total state installed electrical capacity apart from intermittent sources of power to the utilities such as wind and cogeneration. However, like oil and gas reservoirs, geothermal reservoirs ultimately become depleted, thus it is not an infinite resource.

Windpower

The wind farms in California are the largest in the world. During 1985 the number of turbines increased by 25% (Table 4) partially in response to the impending expiration of federal tax credits and favorable depreciation schedules for alternative forms of energy. State tax credits are scheduled to expire at the end of 1986. Vertical axis turbines with ratings between 50 and 100 kw have been the overwhelming choice, and they are largely of US manufacture although increasingly foreign designs are being installed.

Table 4 Windpower installations in California as of January 1

Location	Capacity (MWe) 1985	Capacity (MWe) 1986	Number of turbines 1985	Number of turbines 1986
Altamont Pass area, 45 miles east of San Francisco	318	479	3900	5154
San Gorgonio Pass, Riverside County near Palm Springs	150	190	2450	2801
Tehachapi Pass, Kern County	132	186	1950	2544
Mohave Desert, Kern County	7	(unavail-able)	150	(unavail-able)
Boulevard, San Diego County	4	1.25	16	51
Carquinez Strait, Solono Co.	3	.63	10	6
Salinas Valley	0	.1	0	4
TOTAL	609	857	8470	10560

Source: California Energy Commission, Results from the Wind Project Performance Reporting System, 1st Quarter 1985, Staff Report P500-85-007 (December 1985) and 4th Quarter 1985, Staff Report P500-86-003 (June 1986)

Under PURPA the price that producers received for power generated was based on "avoided costs". Price per kwh paid small producers has been as high as 8.9 cents for on peak power; however with decline in oil and gas prices it fell to 6.3 cents at year-end, which together with the expiration of federal tax credits, impacted the growing industry.

Capacity factors in the fourth quarter of 1985, typically a period of minimal winds in the state, averaged 5% compared to the estimated potential capacity factor of 15%. The total amount of electricity produced for the year was 0.67 billion kwh. To put the production into perspective, 175 billion kwh was consumed in the state in 1985. The California Energy Commission has computed that wind power met the annual electrical needs of more than 110,000 typical California residences. Note, however, that the wind and power produced therefrom can not in reality supply electricity to any given number of residences without back up power plants to provide power during seasons of the year and hours of the day when the wind does not blow.

Alternate forms of energy have long been advocated by environmental and anti-nuclear groups in California. So it is ironic that some of these advocates are objecting to the environmental pollution posed by the windmills. Numerous lawsuits have been filed against windmill operators in the San Gorgonio area, and the city of Palm Springs has sued the Department of Interior's Bureau of Land Management for mismanaging wind farms on government land. Wind farms, the city claims, are noisy, ugly and have despoiled a pristine desert corridor[20]. Environmental groups have complained about decimation of flocks of migrating birds and disturbance of the delicate ecosystem of the region.

Cogeneration

Cogeneration on the part of industrial, agricultural and oil producing companies continued to pose problems to both utilities and to utility regulators. Under the Public Utility Regulatory Act of 1978 (PURPA) utilities are required to buy electricity produced by cogenerators at prices

commensurate with the cost of power produced by a new power plant, the so-called "avoided cost". Within a short period of time the utilities were overwhelmed by proposals from small generators and in 1985 signed contracts to buy power from producers with an aggregate nominal capacity of more than 16 GWe. Total conventional installed capacity in the state is about 42 GWe. The principal utility complaints to the Public Utilities Commission (PUC) related to the inordinate high price paid for the purchased power under PURPA, the fact that in some areas the power was not needed, and the difficulty of making defensible plans to meet future demand in view of the intermittent nature of most power purchased from the cogenerators.

A total of about 6 billion kwh can be attributed to cogeneration in 1985 (21×10^{12} Btu). Its impact on the state's electrical supply can be assessed by inspecting Figure 1. Power from cogeneration is included in electrical exchanges which after losses equaled 190×10^{12} Btu. Cogeneration comprises about 3 percent of transmitted power despite the high nominal generating capacity associated with it.

In April 1985 the PUC suspended the standard rate contract that had been the basis for power purchases under PURPA until July 1986 in order to develop another formula. The move was designed to stem the flood of cogeneration applications, since any new schedule was expected to be less favorable to the cogenerators, as well as to assess what appeared to be an unstabilizing influence on the state's major utilities. In the interim, only short term contracts could be negotiated which severely hampered funding of proposed projects. In mid-1986 a new scheme was developed which hinged on utility and PUC estimates of size and cost of needed additional power, allocations to cogeneration for some portion of the new power needed, and a bidding system in instances where a utility's cogenerator allotment is

oversubscribed. A novel feature is that cogenerators will get more per kwh if they tailor their production to fit annual and diurnal demand. It remains to be seen how the new rules will influence what has been a stampede to sign cogeneration contracts with the utilities in the state.

Self Generation

Self generation is defined as electrical energy that is produced primarily for internal use with any surplus electricity being sold to a utility[21]. Thus in those instances where excess power is sold to utilities, self generated power can be considered to be cogenerated power as well. The amount of power sold to the utilities is a matter of record; however, the amount that is used internally by the private generators is not. The motivation of the self-generator is electricity at lower cost. California's electrical rates are well above national average. Falling fuel prices have encouraged the conversions.

In recent years the trend in industry to generate internally has increased to the point that energy agencies such as the California Energy Commission have felt it was necessary to estimate present and future self generation capabilities. The agencies' concern has to do with the mix of fuels, or lack thereof, used to generate the power and the impact on rates that must be levied on the remaining utility customers in order to recover fixed costs of increased reserve margins the utilities must maintain in order to supply stand-by power to self-generators, development of new sources of pollution, and uncertainties in predicting future demand and need for future base load power plants.

The California Energy Commission has estimated that 2.94 billion kwh was produced in 1985 by industrial and commercial companies and

institutions[22]. That equates to 10 x 10^{12} Btu that are <u>not charted on the 1985 flow diagram</u> (Figure 1) or a little over one percent of the total amount of transmitted electricity. The bulk of it was produced in the food processing, lumber, paper, petroleum refining, chemical, electronic and cement industries. Together with cogenerated power sold to utilities, these new sources of power are approaching five percent of electricity generated in the state*, a significant perturbation in total supply.

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*Cogeneration (21 x 10^{12} Btu) plus self generation (10 x 10^{12} Btu) is 4.5% of transmitted (673 x 10^{12} Btu) plus self generated power (10 x 10^{12} Btu).

Appendix A

Data Sources for California Energy Supply (1985)

Production	Source
Crude Oil including Federal Offshore and Lease Condensate	Ref. 7
Associated and Nonassociated Natural Gas	Ref. 7
Electric Utility Fuel Data	Ref. 8, Table 23
Electrical Generation (hydro, nuclear , oil, gas, geothermal)	Ref. 8, Table 6
Wind	Ref. 9
Imports	
Natural Gas Foreign and Domestic	Ref. 10, Table S 5
Crude Oil Foreign and Domestic	Ref. 11, Table 1
Oil Products Foreign and Domestic	Ref. 11, Fourth Quarter, Table A-1
Coal	Ref. 12, Table 24
Electrical Power Net Exchange	Ref. 10, Table S 2
Coal	Ref. 10, Table S 1 and S 2
Exports	
Oil Products Foreign and Domestic	Ref. 11, Fourth Quarter, Table A-1
(not including bunkering fuel supplied at California ports)	

Appendix B

Data Sources for California End Uses (1985)

Net Storage and Field Use	
Natural Gas	Ref. 10, Tables S 4 and S 5
Transportation	
Crude Oil	
Gasoline, aviation and jet fuels	Ref. 11, Fourth Quarter, Table A-1 (CA supplied)
Taxable Diesel Fuel (i.e. for public highways)	Ref. 13
Vessel Bunkering (includes international bunkering)	Ref. 14, Table A-9
Rail Diesel	Ref. 14, Table A-9
Military Use	Ref. 14, Table A-10
Natural Gas	
Pipeline fuel	Ref. 15, Table 13
Industrial, Government, Agriculture, etc	
Natural Gas	By difference
Coal	Ref. 12, Table 24
Electricity	Ref. 8, Table 45
Crude Oil	By difference
Non Energy Applications	
Crude Oil and LPG	
Asphalt	Ref. 16
Petrochemical feedstock	Ref. 17
Waxes, lubricating oils, medicinal uses, cleaning	Ref. 11, Table A-5
Natural Gas	
Fertilizer	Est. from last year's figure
Residential and Small Commercial	
Natural Gas	Ref. 18, Tables 22 and 23
Crude Oil and Other Oils (kerosene, residual, and distillate)	Ref. 14, Tables A-4, A-3 and A-2
LPG	Ref. 17
Miscellaneous "off highway" Diesel	Ref. 14, Table A-10
Electricity	Ref. 8, Table 45

Appendix C

Conversion Units

Energy Source	Conversion factor, 10^6 Btu
Electricity	3.415 per MW.h
Coal	22.6 per short ton
Natural Gas	1.05 per MCF
LPG	4.01 per barrel
Crude Oil	5.80 per barrel
Fuel Oil	
Residual	6.287 per barrel
Distillate, including diesel	5.825 per barrel
Gasoline and Aviation Fuel	5.248 per barrel
Kerosene	5.67 per barrel
Asphalt	6.636 per barrel
Road Oil	6.626 per barrel
Synthetic Rubber and Miscellaneous LPG Products	4.01 per barrel

Assumed Conversion Efficiencies of Primary Energy Supply

Electric power generation	
Hydro power	90%
Coal	30%
Geothermal	18%
Oil and Gas	33%
Uranium	32%
Transportation Use	25%
Residential/Commercial Use	70%
Industrial Use	75%

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