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U.S. ENERGY FLOW - 1989

I. Y. Borg
C. K. Briggs

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Lawrence Livermore National Laboratory

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ABSTRACT

Energy consumption in 1989 closely resembled that in 1988 although a modest increase of less than 2% was indicated by preliminary data. After steady increases for almost a decade, energy used in the transportation sector stabilized. Oil imports rose 57% over those in 1982 and constituted 41% of total supply. By year-end domestic crude oil production fell to 1964 levels. Coal production set records with the bulk of it dedicated to electrical production. Natural gas consumption remained near that of 1988; however imports from Canada played a larger role in supply. High rates of growth in electrical consumption associated with the last decade were not sustained in 1989. Nuclear power reactors contributed 19% to total supply, a percent that is expected to fall as new non-nuclear power sources come on line in response to anticipated continued growth in demand.

INTRODUCTION

United States energy flow charts tracing primary resource supply and end-use have been prepared by members of the Energy Program and Planning groups at the Lawrence Livermore National Laboratory since 1972.[1,2] They are convenient graphical devices to show relative size of energy sources and end-uses since all fuels are compared on a common Btu basis. The amount of detail on a flow chart can vary substantially, and there is some point where complexity begins to interfere with the main objectives of the presentation. The charts shown here have been drawn so as to remain clear and be consistent with assumptions and style used previously.

ENERGY FLOW CHARTS

Figure 1 and 2 are energy flow charts for calendar years 1989 and 1988[3] respectively. The 1989 chart is based on provisional data published by the Energy Information Administration of the Department of Energy. Conventions and conversion factors used in the construction of the charts are given in the Appendix. For comparison with earlier years, consumption of energy resources is given in Table 1. These data in many instances contain revisions of data published by the Department of Energy.

U.S. Energy Flow – 1989
Net Primary Resource Consumption 81 Quads

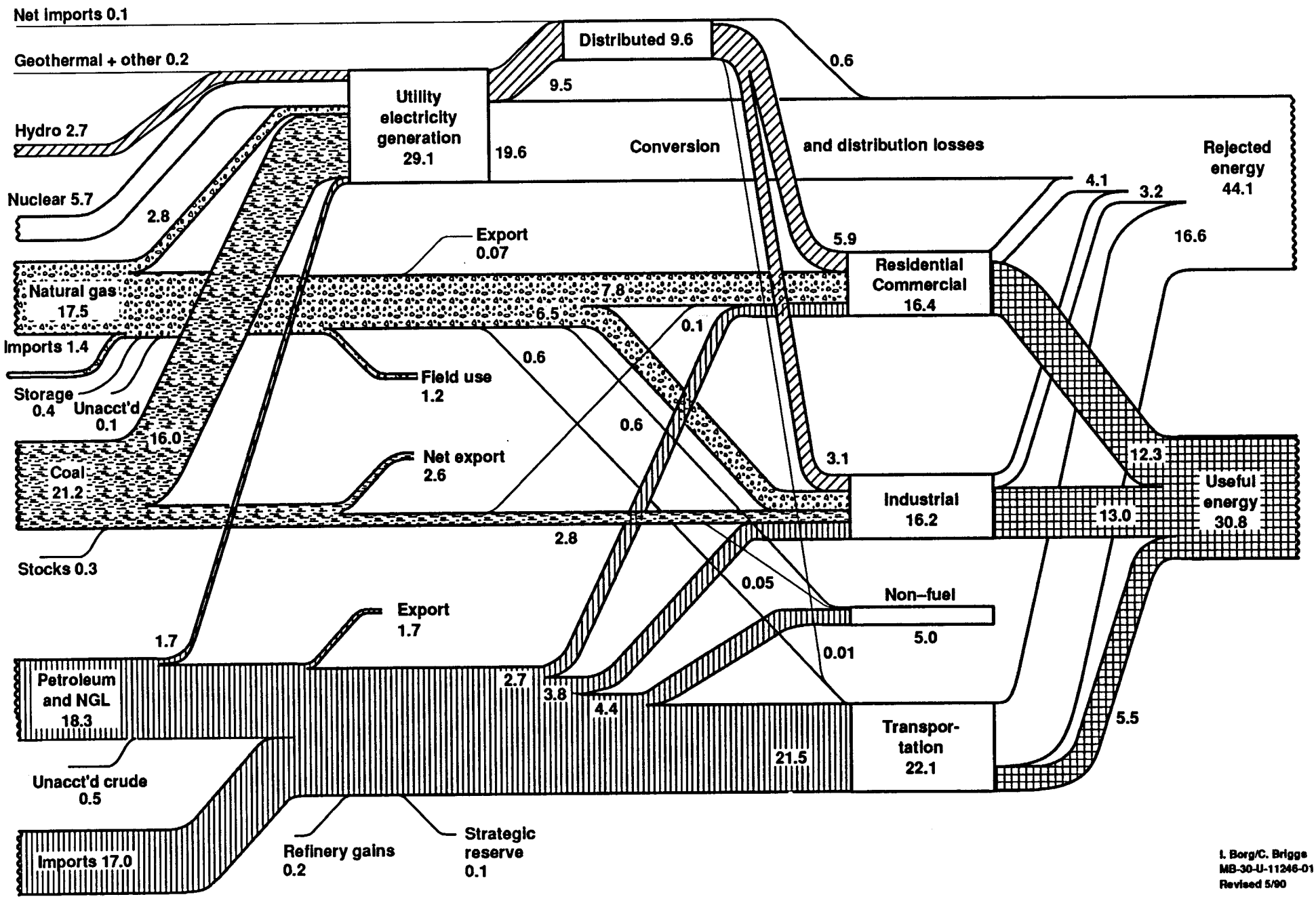

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Figure 1

U.S. Energy Flow – 1988
Net Primary Resource Consumption 80 Quads

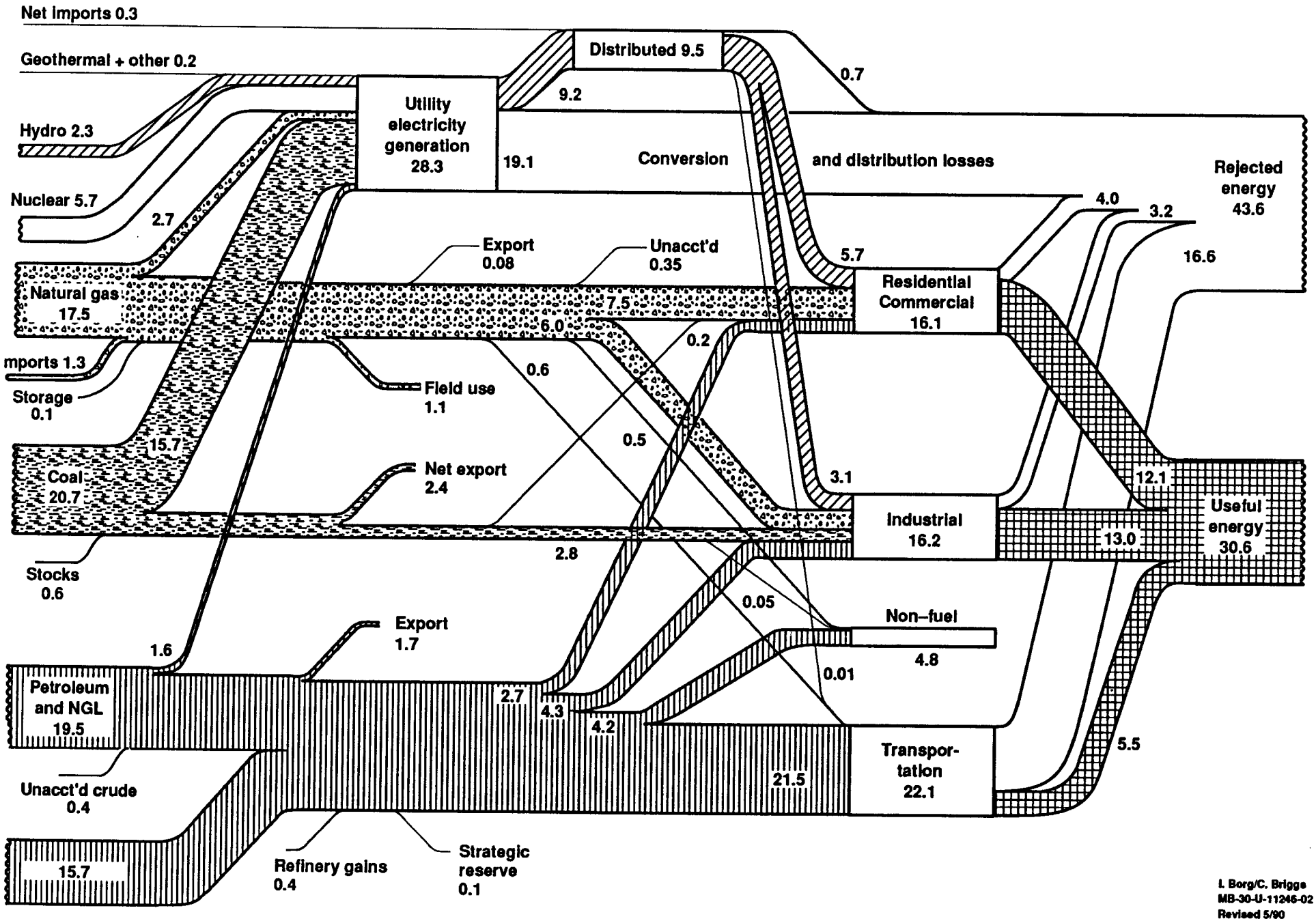

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Figure 2

Table 1. Comparison of Annual Energy Use in U.S.[4]

	Quads							
	1982	1983	1984	1985	1986	1987	1988	1989
Natural gas production	18.26	16.53	17.93	16.91	16.47	17.05	17.49	17.53
Imports	0.93	0.94	0.86	0.93	0.75	0.99	1.30	1.38
Crude oil and NGL								
Domestic crude & NGL	20.50	20.58	21.12	21.23	20.53	19.89	19.54	18.31
Foreign imports (incl. products & SPR)	10.80	10.66	11.44	10.62	13.21	14.18	15.71	16.98
Exports	1.75	1.58	1.55	1.67	1.68	1.63	1.74	1.84
SPR storage reserve*	0.37	0.49	0.42	0.24	0.11	0.17	0.11	0.12
Net use (minus exports and SPR)	29.18	29.17	30.59	29.94	31.95	32.27	33.40	33.33
Coal production (incl. exports)	18.64	17.25	19.72	19.33	19.51	20.12	20.74	21.23
Electricity								
Hydroelectric (net)								
Utility	1.06	1.13	1.10	0.96	0.99	0.85	0.76	0.90
Imports	0.31	0.37	0.41	0.42	0.37	0.48	0.33	0.13
Geothermal & other (net)	0.02	0.02	0.03	0.04	0.04	0.04	0.04	0.04
Nuclear (gross)	3.13	3.20	3.55	4.15	4.47	4.91	5.66	5.69
Fossil Fuel (gross)	17.49	17.75	18.53	18.79	18.59	19.37	20.12	20.48
Gas	3.34	3.00	3.22	3.16	2.70	2.94	2.71	2.85
Coal	12.58	13.21	14.02	14.54	14.44	15.17	15.85	15.95
Oil	1.57	1.54	1.29	1.09	1.45	1.26	1.56	1.68
Total transmitted energy	7.96	8.25	8.64	8.85	8.86	9.25	9.55	9.61
Residential and Commercial	14.63	14.40	15.01	14.90	14.83	15.20	16.10	16.44
Industrial+	20.02	19.40	21.06	20.41	20.04	21.01	22.14	22.43
Transportation	19.04	19.11	19.85	20.09	20.74	21.35	22.16	22.12
Total consumption** (DOE/EIA)	71	70	73	74	74	77	80	81

* Strategic petroleum reserve storage began in October, 1977.

\+ Includes field use of natural gas and non-fuel category and excludes electrical losses.

* * Note that this total is not the sum of entries above.

COMPARISON OF ENERGY USE WITH 1987 AND EARLIER YEARS

For the third year, total energy use in the U.S. increased albeit at a smaller rate (1.7%) than in the previous two years (Figure 3). The increase occurred despite higher crude oil prices and a slowdown in national economic growth. Small increases were registered in the residential/commercial and industrial end-use sectors (Table 1) with the residential/commercial sector recording the largest on a percentage basis. Energy use for transportation remained very close to 1988 levels based on preliminary data.

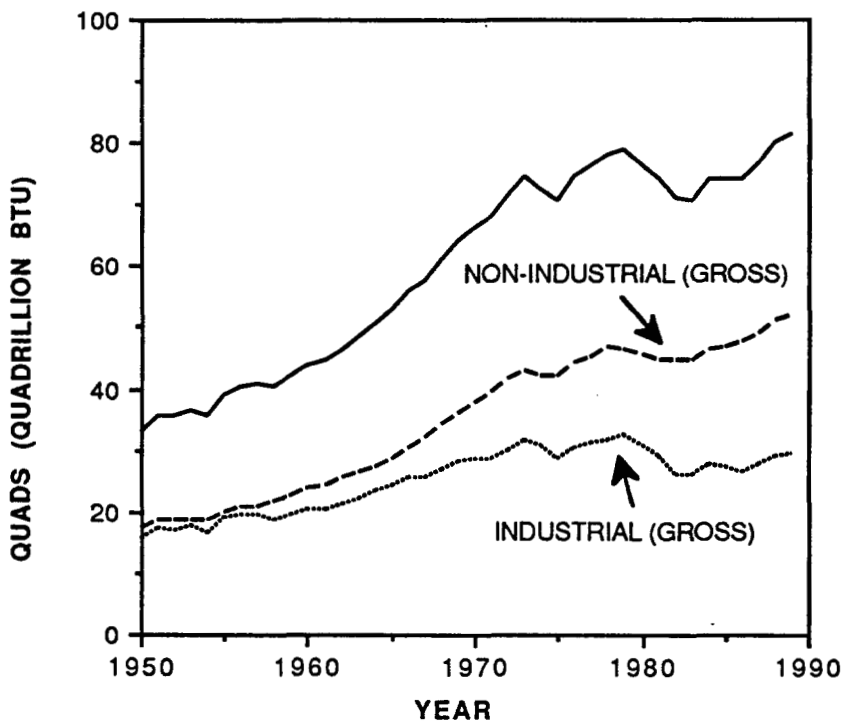


Figure 3. Energy use in U.S.

Source: Annual Energy Review, 1989, DOE/EIA
Gross electrical use is plotted.

The U.S. trade deficit grew nearly to $111 billion of which the cost of imports of petroleum and petroleum products contributed $50 billion based on preliminary estimates.[16] The value of petroleum and product imports was about $10 billion higher than in 1988 (Figure 4). This is considerably below the record of $77 billion set in 1980 when crude oil prices were nearly at

their peak. On a volumetric basis, net imports of petroleum and products were at 1976 levels, still below their all time high in 1977.

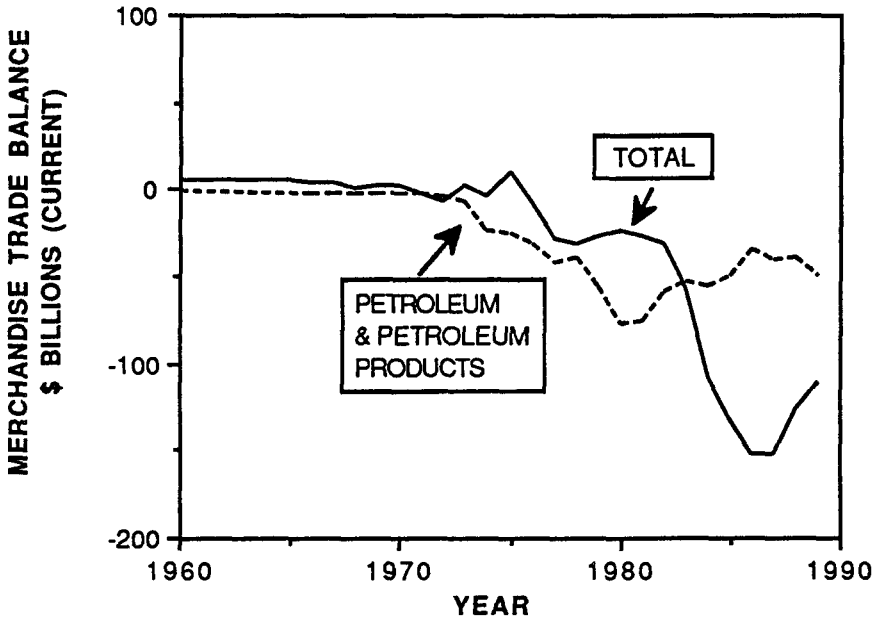


Figure 4. Contribution of imports of petroleum and petroleum products to the U.S. trade deficit

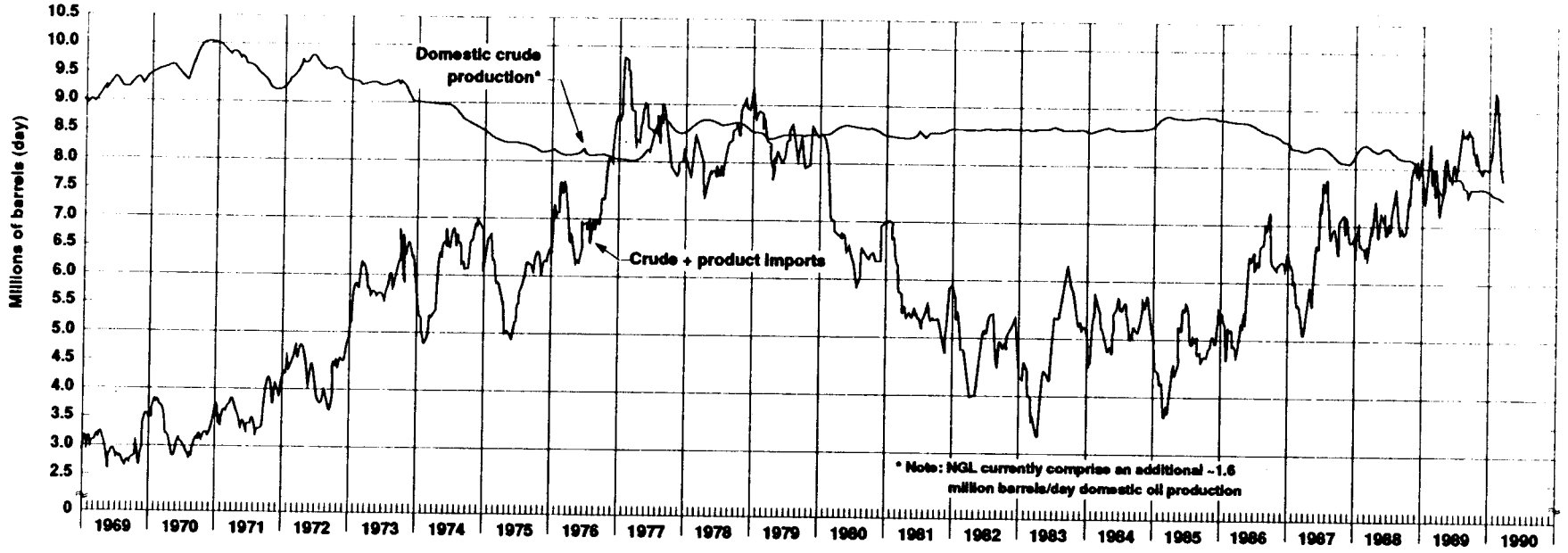
Source: For 1960-1987: U.S. Statistical Abstracts, Table 1247 (1971); Table 1331 (19740; Table 1521 (1978); Table 1491 (1982-3); Table 1350 (1988); Table 1369 and 1377 (1989). For 1988-1989; Survey of Current Business *70* Tables 4.2 and 4.3, April 1990.

DEMAND AND SUPPLY OF FOSSIL FUELS

While net oil use declined by a small amount, coal production reached record levels with the bulk of it going to electrical generation. Both oil and natural gas imports increased substantially. Net imports of petroleum reached 41% of total consumption as compared to 38% in 1988[10] (Figure 5). The increase came largely from OPEC nations,

PETROLEUM IMPORTS AND DOMESTIC PRODUCTION

Moving four week average



REFINER ACQUISITION COST OF CRUDE OIL

Composite domestic and imported

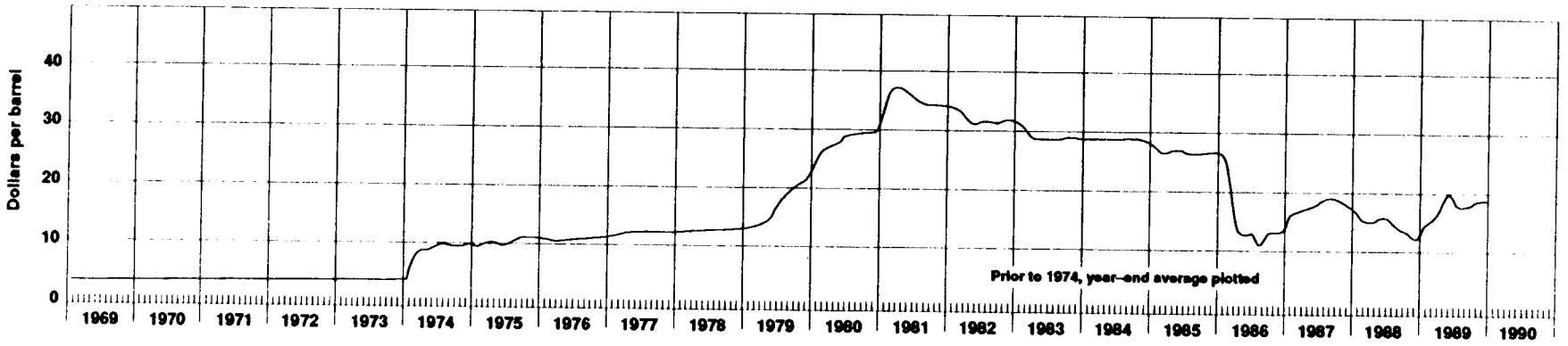


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Figure 5

which supplied 58% of imports as compared to 53% in 1988. Domestic crude oil production continued the decline which started in 1986, and by the end of 1989 it reached 1964 levels. In addition to declines in the lower 48 states, Alaskan production fell due to the closure of the Port of Valdez to all tanker traffic as a consequence of the 260,000 barrel oil spill from the tanker *Exxon Valdez.* Although masked by increases in production from smaller fields in the North Slope, Alaska, the super-giant Prudhoe Bay field began its long anticipated decline. All indicators of exploratory activity (number of rigs operating, seismic crews and well completions) were below 1988 levels despite the fact that the average refiner's acquisition price for a barrel of oil rose from $13.98 in 1988 to $19.51 in 1989.

Although natural gas consumption was close to 1988 levels, imports from Canada increased 6% and the pipeline companies were poised to increase the amounts substantially in the future. Gas exports to the U.S., principally to California and the Midwest, account for about 39 percent of Canadian production; however growth in Canadian imports has been hampered by inadequate pipeline capacity. Efforts to increase Canadian imports centered on numerous licensing applications submitted to the Canadian National Energy Board, obtaining commitments from customers, obtaining approval for pipeline construction from the Federal Energy Regulatory Commission and finally financing the projects. Other planned pipelines will tap mid-continent and Rocky Mountain area gas. The two regions targeted for new gas supplies are the northeast U.S. and California.[11] Imports into the northeast represent a turn from traditional heating and power generation fuels. Additional supplies for California, which already accounts for 10% of the U.S. demand for natural gas, is directed principally at the enhanced oil recovery market. Historically, steam used in California's heavy oil fields has been raised with lease crude which is in the process of being replaced by natural gas. Additional uses anticipated are utility electrical generation, which in 1988 accounted for thirty percent of demand in the state,[12] and the growing cogeneration market.

With the passage of the gas decontrol bill by both Houses of Congress in 1989 the last vestiges of well head price controls will end by January 1, 1993, or earlier if contracts expire or are renegotiated before then.[13]

The first shipment of Algerian liquefied natural gas (LNG) reached Trunkline's Lake Charles, LA, terminal at year end.[14] Panhandle Eastern Corp., parent of Trunkline LNG Co., plans to buy the LNG equivalent of up to 3.3 trillion CF of natural gas over 20 years from Sonatrach, the Algerian national gas company. To put this amount into perspective, the U.S. consumes about 19 trillion CF per year. The Lake Charles terminal was built in the late seventies and received shipments from Algeria until 1983 when purchases ceased because of adverse market conditions.

The U.S. is second only to Australia as a source of coal to world markets. About ten percent of 1989 record U.S. production was exported; two-thirds of the exports were metallurgical coal, which went principally to Japan, Canada, Italy Belgium, Luxembourg and Brazil. These exports contributed approximately $4 billion to the U.S. balance of payments.[15]

U.S. ELECTRICAL SUPPLY AND DEMAND

The high growth rate in electrical consumption that has been recorded in the previous few years was not attained in 1989. There was a modest increase of less than 1% in electricity distributed to the various end-use sectors, which corresponds to an increase of approximately 3% in gross generation taking conversion and distribution losses into account.

Coal continues to be the principal fuel for power generation in the U.S. (Figure 6); however due to a slightly larger hydroelectric contribution in 1989, its share of total generation fell about one percent. Canadian electricity sales to the U.S. were down due to a combination of increased Canadian domestic demand and low rain and snowfall effecting the capacity of the large Canadian hydroelectric projects which supply surplus electricity to the U.S.[14]

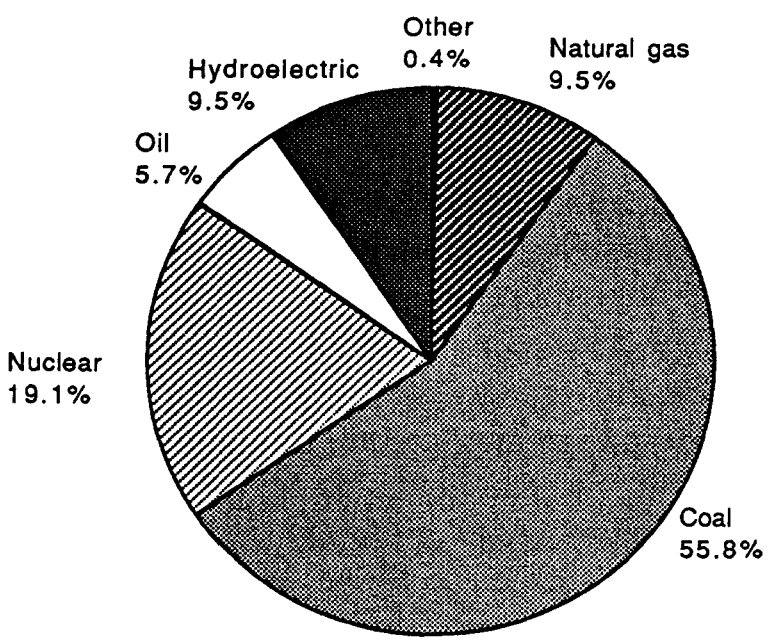

Figure 6. Fuels for U.S. electrical generation-1989
Source: Monthly Energy Review, DOE/EIA-0035(89/12) Table 7.1

NUCLEAR POWER

Although the nuclear contribution to electrical generation in the U.S. is low (19.1%, Table 2) in relation to that in many other countries, including Bulgaria, Czechoslovakia, Spain, Taiwan and S. Korea[5], in terms of the number and size of the nuclear installations in the country, the U.S. has no peer. There were 110 operable nuclear plants at year-end, which is close to the number of plants in the USSR and France combined. The U.S. total represents 26% of the world's total and 30.9% of the world's net installed nuclear capacity.[6]

In 1989 two nuclear units (South Texas-2 and Vogtle-2) began commercial operation. Two nuclear plants were shut down (Fort St. Vrain and Rancho Seco) and Seabrook received its low power operating license.

The Fort St. Vrain reactor was an attempt to scale up a helium-cooled graphite-moderated reactor to commercial size. The plant never operated satisfactorily and had one of the poorest operating records in the nuclear industry. Because of its poor performance, Public Service Co. of Colorado agreed in 1986 to stop charging customers for the cost of operating the plant and to end operations in June, 1990. In August 1989 it was closed down 10 months ahead of schedule and is expected to reopen as a gas-fired plant in 1994.[7] It is thus following the path of the 1370 MW Midland nuclear plant, Michigan, which was converted to gas after construction was 85 percent complete, and the Zimmer nuclear plant in Ohio which is scheduled to open in 1991 as a 1300 MW coal-fired plant.[8]

Rancho Seco in California survived a 1988 referendum to close it down, but its troubled operating history which persisted through 1989 mitigated against its surviving the second referendum in the Fall of 1989.

Although the Nuclear Regulatory Agency granted Shoreham on Long Island a full-power operating license in 1989, New York State and Long Island Lighting Co. had already decided to scrap the plant. At year end its ultimate fate had not been decided.

Growing national concern about CO_2 concentrations in the atmosphere and the predicted attendant global warming, has given heart to nuclear power advocates; however no utility has ventured to seriously consider a proposal to build a plant. The last orders placed for nuclear plants (2-Carroll County units of Commonwealth Edison Company) were cancelled in 1988[9]. Despite important revisions in Nuclear Regulatory Agency licensing regulations, the system continues to allow regulatory intervention in plants after they are built. Given the cost of building a nuclear plant, utilities refuse to commit funds without the certainty that the plant will operate once built. In view of the strong growth in electrical demand and the unlikelihood that there will be a nuclear revival in the next decade, in the next twenty years nuclear power's share of generation is likely to drop considerably from its current level of 19% in the U.S.

Table 2. Electrical generation from nuclear power[4]

	Year			
	1986	1987	1988	1989
Total utility electrical generation (bn kWh)	2487	2572	2704	2779
Nuclear contribution (bn kWh)	414	455	527	529
Percent nuclear	16.6	17.7	19.5	19.0
Installed nuclear capacity* (GWe)	85.2	93.6	94.7	97.9**
Number of operable reactors	100	107	108	110**
Annual nuclear capacity factor (%)	56.9	57.4	63.5	62.3

*Net summer capability of operable reactors
** Includes Rancho Seco but excludes Shoreham

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APPENDIX

Data and Conventions Used in Construction of Energy Flow Charts

Data for the flow chart were provided by tables in the Department of Energy Monthly Energy Review, DOE/EIA-0035,[4] the 1989 Annual Energy Review[17] and the Quarterly Coal Report[15].

The residential and commercial sector consists of housing units, non-manufacturing business establishments, health and education institutions, and government office buildings. The industrial sector is made up of construction, manufacturing, agriculture, and mining establishments. The transportation sector combines private and public passenger and freight transportation and government transportation including military operations.

Utility electricity generation includes power sold by both privately and publicly owned companies. The non-fuel category of end-use consists of fuels that are not burned to produce heat, e.g., asphalt, road oil, petrochemical feedstocks such as ethane, liquid petroleum gases, lubricants, petroleum coke, waxes, carbon black and crude tar. Coking coal traditionally is not included.

The division between "useful" and "rejected" energy is arbitrary and depends on assumed efficiencies of conversion processes. In the residential and commercial end-use sectors, a 75 percent efficiency was assumed which is a weighted average between space heating at approximately 60 percent and electrical lighting and other electrical uses at about 90 percent. Eighty percent efficiency was assumed in the industrial end-use sector and 25 percent in transportation. The latter percent corresponds to the approximate efficiency of the internal combustion engine.

There are some minor differences between total energy consumption shown here in the energy flow charts and the DOE/EIA totals given in Table 1. The industrial consumption total in Table 1 agrees with DOE's net industrial total. Both totals include natural gas lease and plant fuel and non-fuel ("non-energy") use, which are shown separately in the flow charts (Figure 1 & 2). Gross industrial consumption plotted in Figure 3 includes electrical conversion and distribution losses, which are not specifically given in Figures 1 & 2. In these figures such losses are included in total electrical generation losses (19.6 Q in 1989) associated with utility generation because they are largely incurred by the utilities supplying the electrical power to the sector.

Conversion Factors

The energy content of fuels varies. Some approximate, rounded conversion factors, useful for estimation, are given below.

Fuel	Energy Content (Btu)
Short ton of coal	22,400,000
Barrel (42 gallons) of crude oil	5,800,000
Cubic foot of natural gas	1,000
Kilowatt hour of electricity	3,400

More detailed conversion factors are given in the Department of Energy's Monthly Energy Review.

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