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U.S. ENERGY FLOW - 1991

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ABSTRACT

Judging from the record of the past four years, energy use in the US has stabilized. Increased energy use due to annual growth in population has been offset by improvements in conversion efficiencies and by a downturn in economic activity. By all accounts, 1991 was a recession year with unemployment at 6.7% and the gross domestic product (GDP) in constant dollars declining for the first time since 1982. The decline was registered in the Goods component of the GDP as contrasted to the Services component which actually increased. Energy consumption in the residential/commercial sector rose while use in the industrial and transportation sectors fell.

Oil use declined in 1991 which, together with slightly increased domestic production, led to a smaller volume of imports. Net imports of crude oil and petroleum products comprised 40% of supply. Two thirds of the imports were from OPEC, the largest supplier being Saudi Arabia. For the first time in 6 years domestic oil production grew slightly due to the increases in Alaska, Federal Offshore provinces and increased natural gas liquid production. Natural gas use also increased slightly. In order to enlarge the US gas supply, there were numerous gas pipelines either under construction or in the approval or proposal stage. The bulk of the new supplies is to be of Canadian origin.

Following a trend of many years' standing, the amount of transmitted electrical energy increased, albeit at less than former rates. Coal remained the principal source of electrical power in the US. The next largest contributor was nuclear energy (22%) which continued to grow by virtue of improved capacity factors and the return to service of reactors that had been shut down. Renewable sources of energy comprised 0.6% of power transmitted by the utilities. That share is below the 1987 historical high. New power plants using geothermal, wood, waste, wind, photovoltaic and solar thermal energy sources have not been large enough to compensate for the natural depletion that set in at California's giant geothermal field (The Geysers) in 1988.

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

Figures 1 and 2 are energy flow charts for calendar years 1991 and 1990[3] respectively. The 1991 chart is based on provisional data published by the Energy Information Administration of the Department of Energy.[4] 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 previously reported in this series.

COMPARISON OF ENERGY USE WITH 1990 AND EARLIER YEARS

Energy consumption for the past four years has remained virtually unchanged (Table 1). The last substantial increase was registered in 1988. Consumption in individual major end-use sectors (residential/commercial, industrial and transportation) has shown similar trends although small up and down fluctuations over the period have been registered by all. In 1991 residential/commercial use rose 3%, industrial and transportation use each fell by approximately 1%. The small declines are attributed to an economic slowdown which affected 1990 energy consumption as well.

By most measures 1991 was a recession year in the US. The unemployment rate increased from 5.5 percent to 6.7 percent and real disposable personal income decreased 0.1 percent. Following trends apparent at the end of 1990 (Fig. 3), the gross domestic product in constant dollars declined for the first time since 1982. Proportionately hardest hit by the economic downturn was the construction industry while the collective "Service" industries, which include banking, insurance, health services, real estate, etc., showed a modest increase (Table 2).

Consumption in the transportation sector has changed little between 1988 and 1991. New passenger car standards (CAFE standards) in that period have risen from 26 to 27.5 miles per gallon. However, gains in efficiency for passenger cars have been partially off-set by annual increase in miles traveled,[4] an effect that has been noted starting in 1979, the year following the imposition of the CAFE standards on automobile manufacturers. The increase in miles traveled has been encouraged by the general decline in motor fuel prices (Fig. 4). In constant dollars the decline is even more substantial.

Fuel costs have posed a dilemma for manufacturers – domestic and foreign alike – who must meet CAFE standards. What are perceived by consumers to be low prices have helped spawn an increased demand for bigger cars. With the US Congress urging higher mileage standards and with automobile industry's profits plummeting, some Detroit auto makers are pressing for a stiff gasoline tax to improve sales of smaller, more energy-efficient vehicles.[5] Such a proposal, albeit

U.S. Energy Flow – 1991
Net Primary Resource Consumption 82 Quads

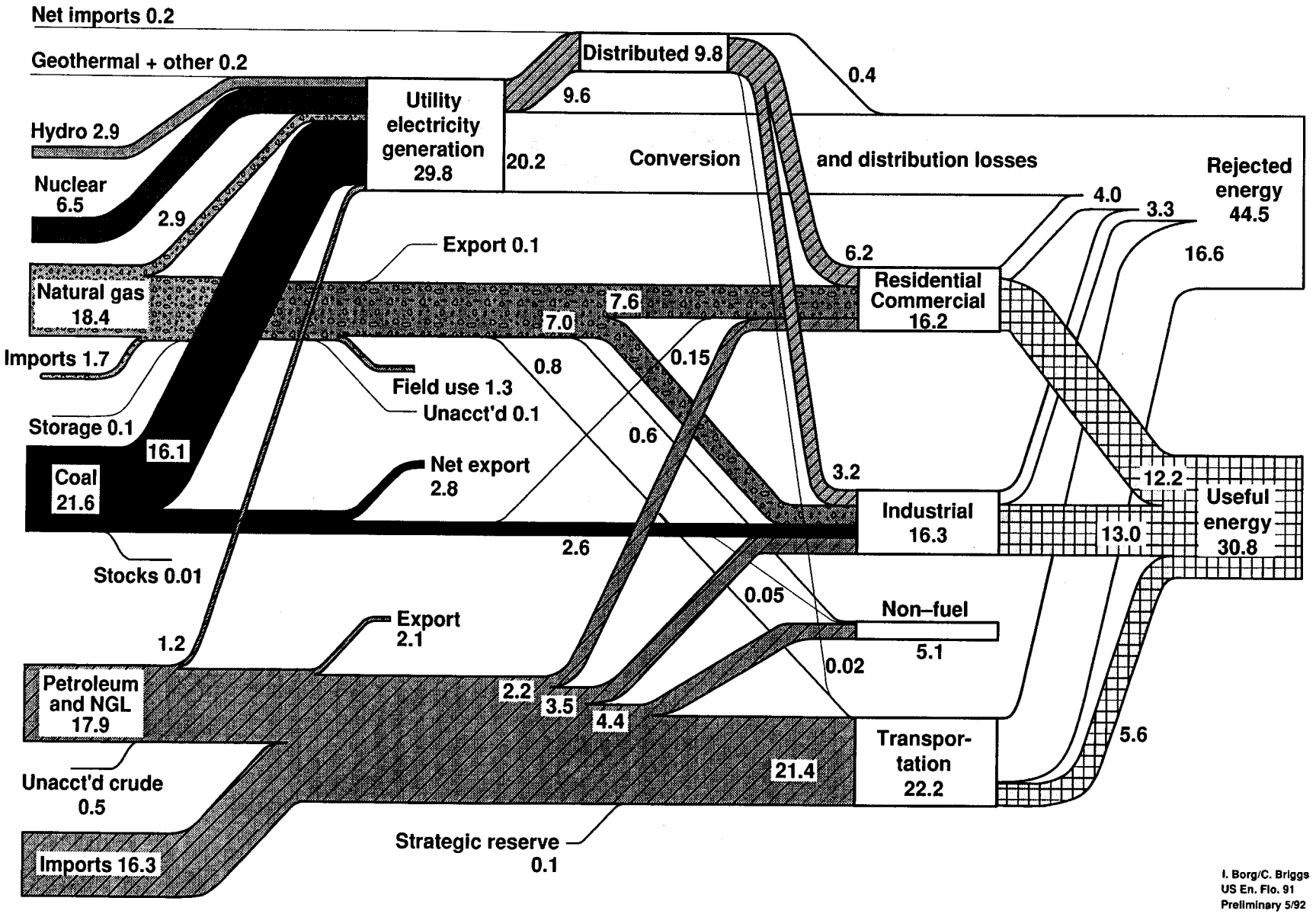

Figure 1

U.S. Energy Flow – 1990
Net Primary Resource Consumption 81 Quads

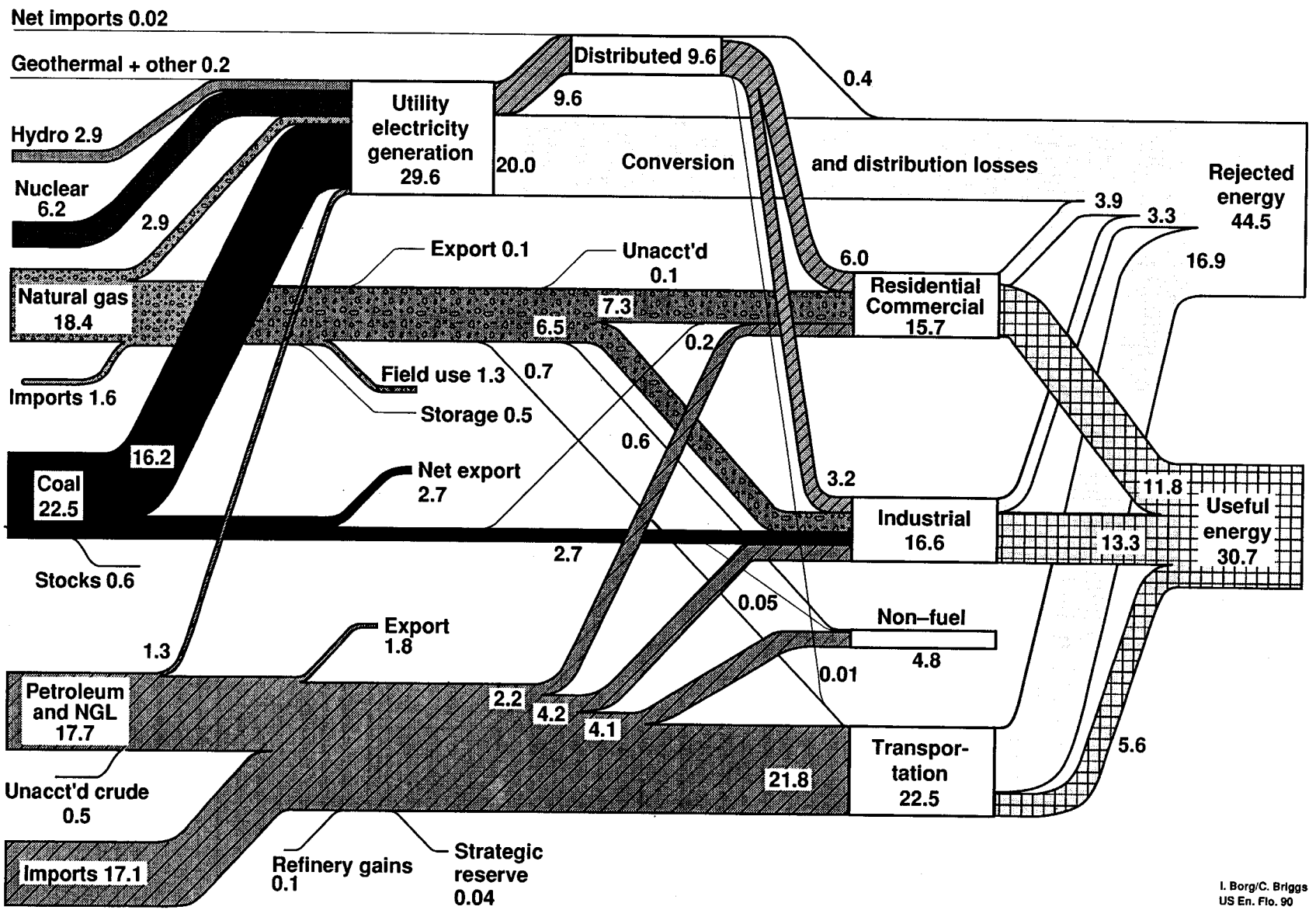

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Figure 2

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

	Quads							
	1984	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**
Natural gas production	17.93	16.91	16.47	17.05	17.52	17.78	18.36	18.42
Net Imports	0.79	0.90	0.69	0.94	1.22	1.28	1.46	1.59
Crude oil and NGL								
Domestic crude & NGL	21.12	21.23	20.53	19.89	19.54	18.28	17.75	17.90
Foreign imports (incl. products and SPR)	11.44	10.62	13.21	14.18	15.72	17.16	17.12	16.25
Exports	1.55	1.67	1.68	1.63	1.74	1.84	1.82	2.13
SPR storage reserve*	0.42	0.24	0.11	0.17	0.11	0.12	0.04	-0.10
Net use (minus exports and SPR)	30.59	29.94	31.95	32.27	33.41	33.48	33.01	32.12
Coal production (incl. exports)	19.72	19.33	19.51	20.14	20.74	21.35	22.46	21.55
Electricity								
Hydroelectric (net)								
Utility	1.10	0.96	0.99	0.85	0.76	0.90	0.96	.94
Imports	0.41	0.42	0.37	0.48	0.33	0.11	0.02	.20
Geothermal & other (net)	0.03	0.04	0.04	0.04	0.04	0.04	0.04	.04
Nuclear (gross)	3.55	4.15	4.47	4.91	5.66	5.68	6.16	6.54
Fossil Fuel (gross)	18.53	18.79	18.59	19.37	20.12	20.56	20.32	21.13
Gas	3.22	3.16	2.70	2.94	2.71	2.88	2.88	2.88
Coal	14.02	14.54	14.44	15.17	15.85	15.99	16.19	16.07
Oil	1.29	1.09	1.45	1.26	1.56	1.69	1.25	1.18
Total transmitted energy	8.64	8.85	8.86	9.25	9.56	9.61	9.60	9.83
Residential and Commercial	15.01	14.89	14.81	15.18	16.10	16.35	15.64	16.09
Industrial+	21.06	20.44	20.14	21.18	22.11	22.37	22.78	22.63
Transportation	19.84	20.07	20.73	21.33	22.16	22.35	22.50	22.26
Total consumption** (DOE/EIA)	73	74	74	77	80	81	81	82

*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.

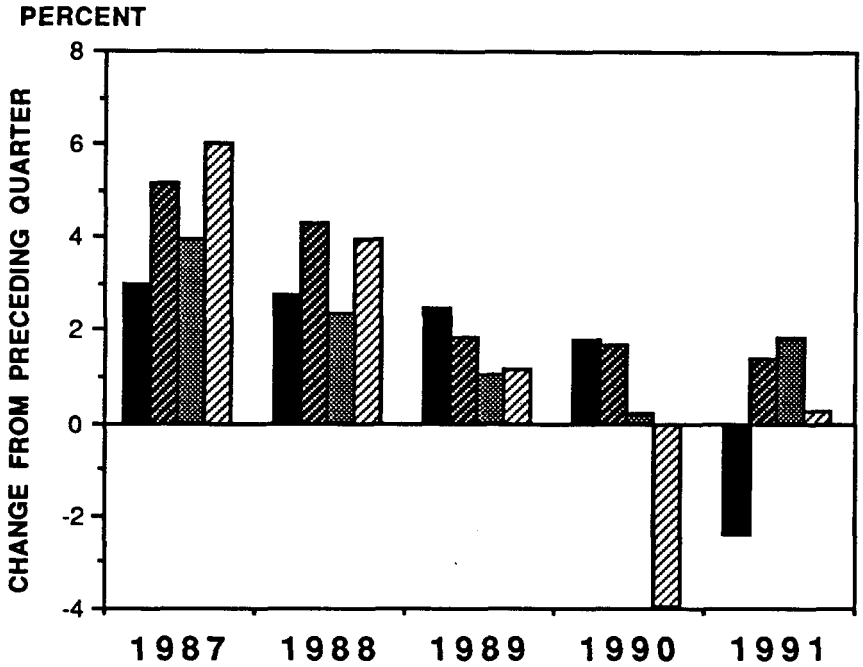


Figure 3. **US economic performance expressed as percent change from prior quarter in the gross domestic product.**
Source: US Department of Commerce, Bureau of Economic Analysis; *Survey of Current Business* 72 No. 1 (January 1992).

Table 2. Gross Domestic Product by Major Type of Product[6]
(Billions of constant 1987 dollars)

	1990	1991

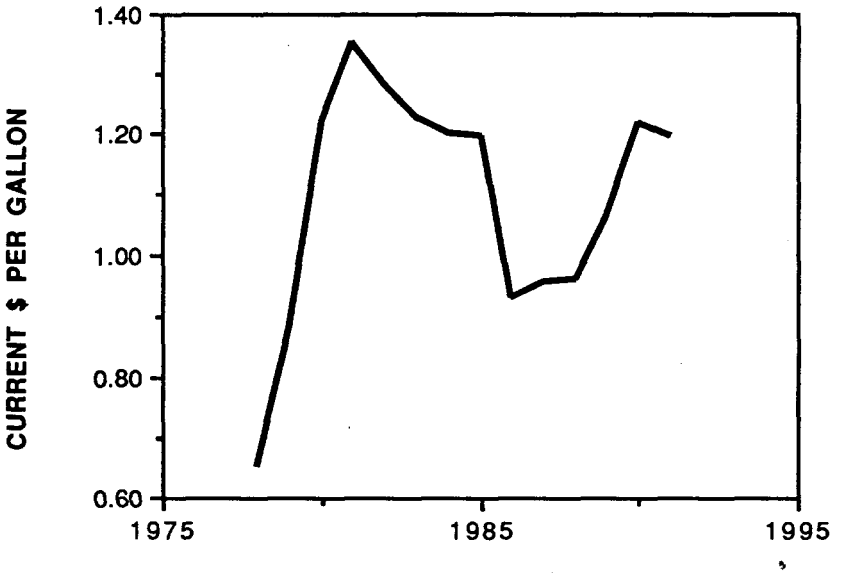


Figure 4. Price of gasoline (all types) including taxes.[4]

with a modest gasoline tax increase, was signed into law at the end of 1991 as part of the Intermodal Surface Transportation Efficiency Act, which is a 6-year overhaul of federal transportation policy.[7] The law earmarks $123.5 billion for highway and safety programs and $31.5 billion for mass transit and includes a flexibility feature whereby up to $80 billion of the highway moneys allocated to the states can be used for mass transit at states' option.[8]

Total electrical consumption rose several percent in 1991. It is a component of consumption in all end-use sectors, and increased use was recorded in most with the largest gains apparent in the residential/commercial sector.

On the supply side, domestic natural gas production was at 1990 levels, but net imports principally from Canada increased thereby bringing the imported share of supply to 9%. Crude oil and petroleum product demand fell in 1991 by almost 3%. As volume of domestic supplies remained unchanged, the decline affected net oil imports. In 1991 they comprised 40% of total supply down from 42% in 1990.

Coal continued as the principal fuel used for electrical generation at US utilities (55%). Contributions from nuclear reactors increased to 22%, and those from hydroelectric and natural gas-fired generating plants were unchanged from 1990 at 10% each. Electricity generated for

distribution from wood, waste, geothermal, wind, photovoltaic and solar thermal energy stood at 0.6%. The total contribution of the group has in fact declined slightly in each of the years 1989-1991. However it is worthwhile noting that private solar thermal and solar photovoltaic installations are largely uncounted in government tallies.

SUPPLY AND DEMAND OF FOSSIL FUELS

OIL SUPPLY

Domestic production

For the first time in 6 years total oil production increased slightly. Preliminary figures indicate the total increase from 1990 was 18,000 barrels per day or less than 0.5%.[9] Nonetheless production from *onshore fields in the lower 48 states* continued its steep decline. The drop was compensated for by approximately a 100,000 barrel per day increase in oil produced as a by-product at natural gas plants associated with larger throughput of natural gas, 25,000 barrels per day from Alaskan fields, and the remainder from Federal Offshore areas principally in California and the Gulf of Mexico.

Herculean efforts have been underway to maintain production at the supergiant Prudhoe Bay field on the north slope of Alaska. The field began its natural decline in 1989. Since then a massive gas injection program and a hydraulic fracturing program have been inaugurated leading to temporary shut down of many wells in 1990 to accommodate installation of equipment associated with expansion of the field's gas handling facilities.[10] Increased production is expected in the next few years; however it is limited by the 2.0 million barrel per day capacity of the Trans-Alaska Pipeline system which carried about 1.8 million barrels per day in 1991. Tests of drag reducing agents in the pipeline have been successful; however it is not certain how long a 2 million barrel per day throughput could be maintained.[10]

Limited production began mid-year at the Point Arguello field, located in Federal waters off of California. Point Arguello field is the largest field discovered (1981) in the US since the Prudhoe Bay field with reserves between 300 and 500 million barrels.[11] The field with three offshore platforms, which accommodate 154 wells, has been idle for 3 years over a dispute with the California Coastal Commission and the County of Santa Barbara over transport of the oil to shore. The choice of Chevron Oil Company, operator of the field for the consortium of owners, is transport by tanker to southern California refineries whereas California public agencies have insisted that existing pipelines to southern California are adequate. A small amount of Point Arguello oil was moved to shore by pipeline and used as a local refinery fuel in 1990, and in 1991

more was piped to northern California where it was loaded onto tankers for shipment to Chevron's El Segunda refinery in southern California. The roundabout routing is estimated to have added $550,000 to the cost of shipping the 205,000 barrels.[12]

The proposal to open the Alaskan Arctic National Wildlife Refuge to oil exploration that was included in the Bush Administration's sponsored energy bill was scuttled by a Senate filibuster in November.[13] Other major provisions of the bill, which was largely based on President Bush's National Energy Strategy Plan, included: speeding the licensing of nuclear power plants by a "one stop" process, easement of natural gas regulatory barriers to pipeline construction, modification of regulations to allow companies other than utilities to produce large scale power, permission for the Secretary of Transportation to set automobile mileage standards, requirement that public agencies run their fleets on alternate fuels and establishment of energy efficiency requirements for new federal and some private buildings.

Oil Imports

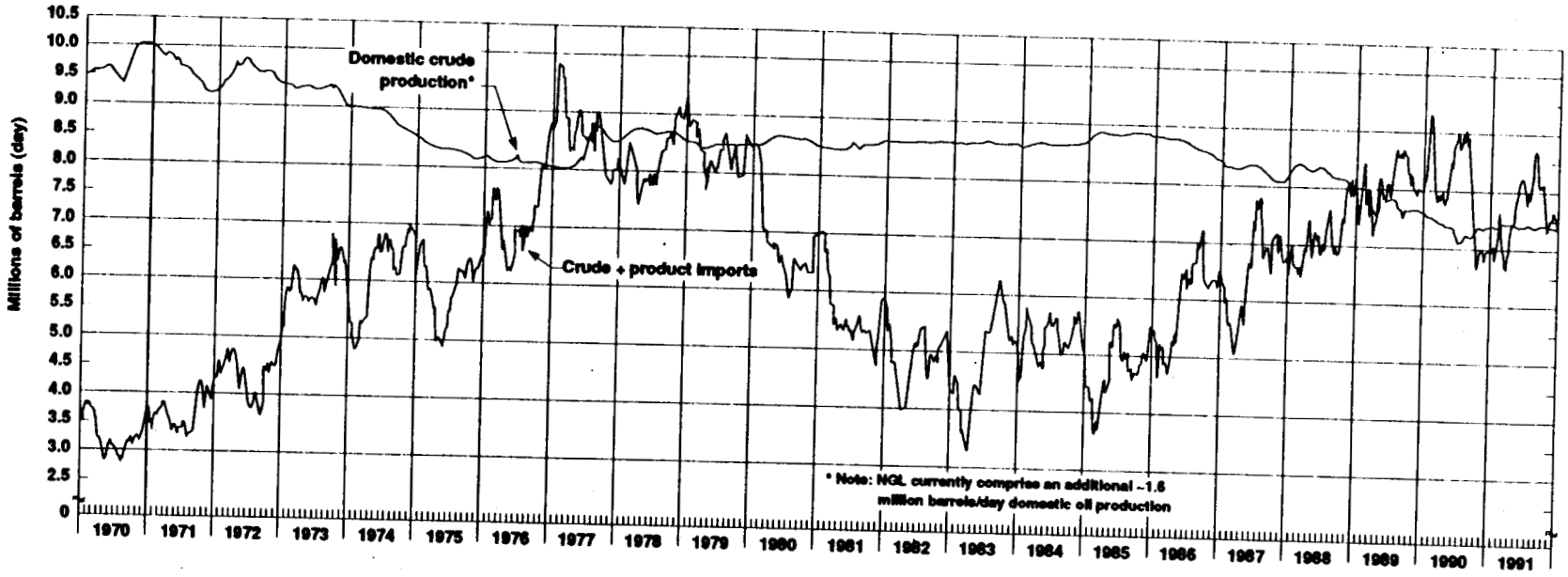
In 1991 forty two percent of the US oil supply (domestic production plus net crude oil and petroleum product imports) was of foreign origin (Fig. 5). Almost two-thirds were from OPEC countries[14] with the largest amount coming from Saudi Arabia followed by Venezuela. The next largest oil sources were Canada and Mexico, who supplied 17 and 12 percent respectively. Net crude oil and product imports fell 586,000 barrels per day to 5,782,000 barrels in 1991; the annual decline was the second in succession. The bulk of the drop was in petroleum products (329,000 barrels per day) which normally comprise about 25% of total oil imports. Decline in oil imports occurred throughout the year; however the largest declines were registered January through April reflecting worldwide shortfalls associated with the Iraqi-Kuwait conflict and attendant high prices, the deepest effects of the recession (Fig. 3) and the warmest winter on record as reported by the National Climatic Data Center.[15] Winter is considered by meteorologists to be the months of December, January and February.

OIL DEMAND

In 1991 demand for all major petroleum products fell. Similarly demand fell in all major end-use sectors. The greatest change (-4.4%) occurred in the broad industrial sector which includes non-fuel use reflecting the national economic recession. The smallest change (-0.7%) in demand was in the residential/commercial sector where economic factors were to some extent mitigated by an increase in population. The largest demand for oil products is the transportation sector where motor gasoline use fell (0.6%) for the third consecutive year reflecting in part increased motor

PETROLEUM IMPORTS AND DOMESTIC PRODUCTION

Moving four week average



REFINER ACQUISITION COST OF CRUDE OIL

Composite domestic and imported

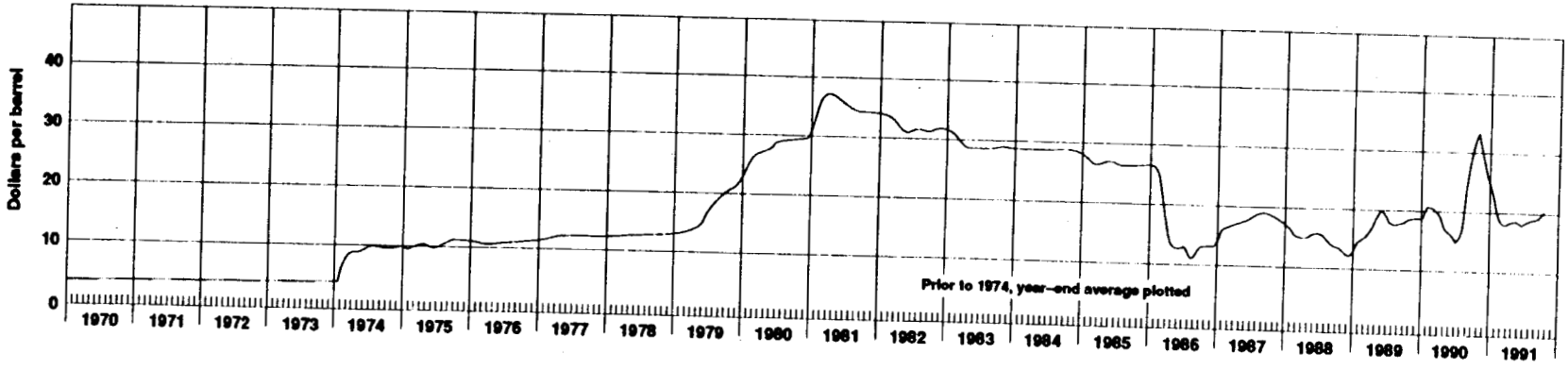


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Figure 5

vehicle efficiencies (Fig. 6). Diesel sales also declined largely in response to decreased commercial and industrial vehicle traffic associated with the economic slowdown. The mild winter contributed to slow sales of distillate fuel oil for space heating. For the first time in 10 years consumption of jet fuels declined, again due to a weak economy and the cessation of the Persian Gulf war which had bolstered both foreign and domestic sales in 1990.

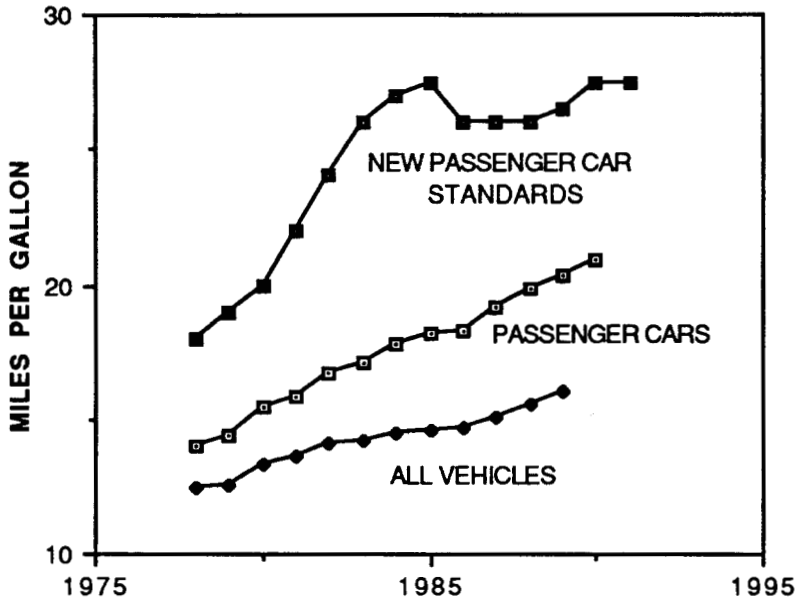

Figure 6. Improvements in vehicle mileage.[16]

NATURAL GAS SUPPLY

Domestic dry gas production was virtually unchanged from 1990; however total disposition increased 4% due to an increase in net imports and withdrawals from storage.

In 1991 the Department of Energy released proven reserve data for natural gas as of December 31, 1990.[17] For the first time since 1981 reserves increased (1.3%) due largely to the increase in coalbed methane reserves of Alabama and the San Juan basin of New Mexico and Colorado. In 1990, 1.4 Tcf of coalbed methane gas was added for a total of 5.1 Tcf representing 3% of all economically recoverable natural gas in the US. Development of this type of "unconventional gas"

has benefited from tax credits which were extended by Congress in 1990. Production and well completions were at all time highs in 1991, and it is anticipated that by 1993 reserves will reach 12 Tcf and that 9000 wells will be producing almost 1.1 Tcf per year.

Natural gas pipeline construction in 1991 reached new heights. Over $11 billion of major new projects were in some stage of development (Table 3). To put perspective on the volumes of gas to be delivered through these approved or proposed pipelines, 25 Bcf/day equates to 9.1 Tcf per year or somewhat less than half of total 1991 natural gas consumption. While some will not go beyond the proposal stage and others, if built, will merely provide shorter travel distances for gas that currently flows through existing pipelines, the amount of "new" gas that will be moving to markets is nonetheless impressive. Canadian imports will be the source of more than two-thirds of the gas to be carried by pipelines that were in the "under construction" or "approved" categories to California and the Northeast. The numerous projects reflect air standards enacted in the Clean Air Act of 1990 that have driven demand as well as the desire on the part of utilities to tap new markets in the northeast and midwest. Further impetus is the expiration of the last of federal price controls in 1992.

Table 3. US Natural Gas Pipeline Construction Projects[18]

	Capacity (Bcf/d)			$Billion
Region	Completed or under construction	Approved	Proposed	
California	2.74	0.72	1.40	4.13
Northeast	2.86	0.48	1.52	2.83
Arkoma basin, OK	1.74	0.70	2.08	1.06
Mobile Bay, AL	0.60	1.50	-	0.25
San Juan basin, NM, CO	2.10	-	-	0.29
Rocky Mts	0.81	0.48	0.62	0.70
Louisiana/Mississippi	0.10	0.60	1.07	0.33
Midwest	0.80	-	0.31	0.32
Offshore	0.53	-	0.38	0.21
South Atlantic	0.48	0.10	-	0.30
Florida	0.14	-	0.40	0.78
Total	**12.89**	**4.58**	**7.78**	**11.19**

NATURAL GAS DEMAND

Total consumption increased about 4% in 1991 despite the warmer than usual 1990-91 winter. Use in all end-use sectors except the electrical utility industry increased by about the same percentage. Natural gas used for electrical generation by the utilities remained at 1990 levels; however the natural gas used by other industries to generate electricity for their own use or in cogeneration operations is not accurately known and thus unrecorded in Department of Energy totals. According to American Gas Association estimates, gas consumed by cogeneration facilities exceeded 1 Tcf in 1991.[19] The amounts of gas used by industry in these fashions have been increasing as judged by the growing amount of cogenerated electricity sold to the utilities annually. In most tallies such natural gas is included in industrial consumption.

The 1991 shares of gas used in the various end use sectors were very similar to those of 1973 (Table 4) although total consumption has dropped somewhat in the 19 year interval. It is curious that the shares are so similar in view of the changes in gas usage that have occurred during the period, e.g., fuel switching from oil and coal in response to air pollution considerations and to international fuel crises; the increased use of natural gas in enhanced oil recovery operations; and the growth of cogenerating and self-generating electrical facilities where natural gas has proven to be the preferred fuel. However, the similarity in the percentages recorded for the various end-use sectors (Table 4) belies the variability that in fact occurred during the period - in both the total

Table 4. Comparison of Gas Shares 1973-1991

End-use sector	1973	1991
	Percent	
Residential	25	26
Commercial	13	16
Industrial	44	42
Electric Utilities	18	16
Total	100	100
Total consumption*	22.0 Tcf	19.6 Tcf

*includes lease, plant and pipeline fuels

amount of gas consumed and in market shares. The greatest variation occurred in the industrial sector where consumption has been affected by economic conditions, pollution regulations and changing technologies. Two thirds of the decline in US consumption of 2 Tcf between 1973 and 1991 can be traced to declining use in industry. It should be noted, however, that the same observation can be made for industrial use of other fossil fuels as well. Total energy consumption in that sector fell 13% between 1973 and 1991.[4]

COAL SUPPLY AND DEMAND

Coal consumption declined by less than one percent in 1991 as all end-uses were affected by a weak economy. Nonetheless the general trend in coal production and consumption in the US has been one of steady increase for the past several decades. In 1991 consumption stood almost 60% over 1973 levels with more than 87% going for electrical generation (Fig. 1). The amount used in coke plants for steel making has fallen to a fraction of what it was in 1973 due to the drop in steel output over the same interval.

Despite the passage of the Clean Air Act Amendment of 1990, coal's share of fuels used for electrical generation is expected to remain at about 55% with more utilities switching to coal with lower sulfur content.[20] Increase in consumption and exports, which now stand at ten percent of production, are anticipated to grow by 45% by 2010 according to Department of Energy projections.[21]

The Clean Air Act Amendments of 1990 mandate a two-phase reduction in sulfur dioxide emissions starting in 1995. The legislation contains some unique features that center on initial SO_2 allowances assigned to each coal-fired plant. The allowances can be shifted among a utility's units and even bought and sold between utilities or even to a yet to be built coal-fired industrial unit. The system thus provides considerable leeway to users in the timing and method of compliance, e.g., through fuel switching, installations of sulfur scrubbers or shut-down. One of the first plants to comply with the sulfur reducing regulations will be the Navajo Generating Station in northern Arizona that has been the center of controversy for twenty years as the source of the haze over the Grand Canyon. The six utility owners plan to install scrubbers between 1997 and 1999 in order to reduce sulfur dioxide emissions by 90%.[22]

ELECTRICAL SUPPLY AND DEMAND

Electrical demand was two percent higher than in 1990 thus again departing from the 3-4% annual growth rates set in the late 80's (Fig. 7).

Cogenerators and self-generators continued to increase in number and output in 1991. As they are not subject to rigid reporting requirements as are the utilities, the power they use or sell is not known accurately. Near the end of 1990 the cogenerating capacity was estimated at 52 GW[23], which is about 7% of total US generating capacity. As they are typically intermittent generators, the amount of power generated is considerably smaller than 7% of the total amount of power generated in the US. Natural gas is the fuel of choice for 60% of cogenerating facilities, and a higher percentage is expected for future installations.

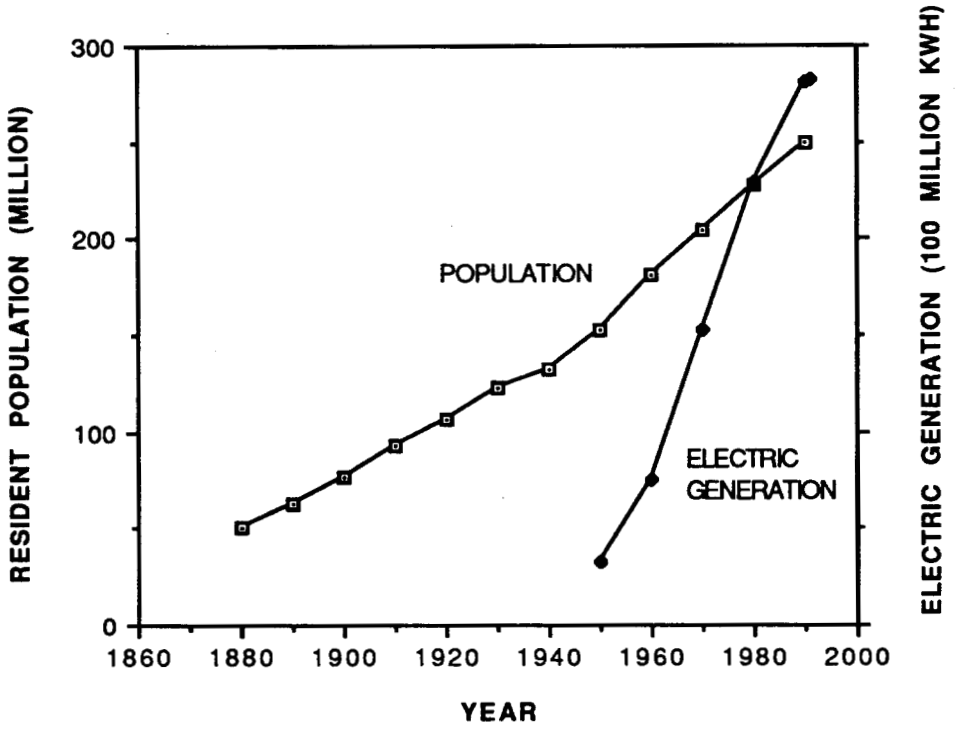

Figure 7. Growth of electrical use
Source: *Annual Energy Review-1991*, US Dept. of Energy, Washington, DC, DOE/EIA-0384(91), (May 1992); *Statistical Abstract of the United States, 1991*, US Department of Commerce, 11th ed. (1991)

The growth of the cogeneration industry has led many independent power producers to look into selling their power to customers of their choosing. Unless Congress forces the utilities to open the electric power transmission lines to them, the option cannot be pursued. Open transmission was part of President Bush's 1990 National Energy Strategy Plan; however legislation that has been proposed has not fared well; the Senate corollary of the House energy bill calling for open access did not come to vote at year end. The utilities who own the transmission lines argue that mandatory "wheeling" of power for independent producers can undermine their system by

crowding out existing transmission.[24] And who would build and make the investment to build new line transmission lines to accommodate the additional loads? Proponents see open transmission as a type of deregulation and therefore as a way to increase competition and diversify electrical supplies. The issues and solution to the problems posed by open access are complex; however because the number of independent producers promises to increase in number and size, the matter is certain to come before Congress again.

In electric power production coal lost some ground to nuclear power but remained the principal fuel for utility generation. The combined contribution of geothermal, wood, waste, wind, photovoltaic and solar thermal energy sources connected to utility distribution systems has remained at 10-12 billion kWh annually since 1985. Because total electrical generation has increased in the same time frame, the share from renewable energy has fallen from its all time high of 0.8% in 1987. That record coincides with the year of the maximum production at The Geysers geothermal field in California.[25] Depletion that set in 1988 at The Geysers is apparent in the data for utility generation of electricity from renewable sources recorded in the ensuing years. Generation at several new, small geothermal plants that have come on line principally in California and Nevada[26] in the past few years has not been large enough to compensate.

NUCLEAR POWER

Nuclear energy's contribution to total electrical generation increased again in 1991 (Table 5). Although the number of operable plants remained the same as in 1990, several restarted in 1991 thereby contributing to both an improved national capacity factor and total nuclear electrical generation. The most noteworthy is the Tennessee Valley Authority (TVA) reactor #2 at Browns Ferry, Alabama that had been shut in 1985.[27] The Browns Ferry plant was at one time the world's largest commercial nuclear plant with three reactors of 1,100 MW each. A fire in 1975 and a series of investigations by federal agencies led to the closure of all three in 1984-85 for repairs. The remaining reactors are scheduled to be restarted in 1994 and 1999.

US nuclear generation comprises a smaller percentage of total generation (21.7%) than in many other countries such as France (75%), Belgium (60%), Sweden (46%) and Switzerland (43%)[28]; however the total amount generated in 1991 exceeded the combined, total electrical net consumption of these countries.[29]

Amidst much controversy the US Nuclear Regulatory Commission at the end of 1991 issued a rule governing regulatory requirements and procedures for the approval of nuclear reactor license renewals.[30] In 2000 the first of many nuclear reactors built in the 1960's reaches the end of its 40 year license to operate. The operators of the reactor Yankee Rowe in Rowe, Massachusetts had

Table 5. Electrical Generation from Nuclear Power[4]

	Year			
	1988	**1989**	**1990**	**1991**
Total utility electrical generation (bn kWh)	2704	2784	2808	2821
Nuclear contribution (bn kWh)	527	529	577	613
Percent nuclear	19.5	19.0	20.6	21.7
Installed nuclear capacity* (GWe)	94.7	98.1**	99.6	99.6
Number of operable reactors	108	110**	111	111
Annual nuclear capacity factor (%)	63.5	62.2	66.0	70.2

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

hoped to apply for a 20 year renewal. The reactor had one of the best operating records in the nuclear industry; however Yankee Atomic Electric Company voluntarily shut it down pending results of technical studies aimed at assessing embrittlement of the reactor vessel in the course of its 31 years of operation.[31] The first license renewal application instead will be filed by the Northern States Power Company for its Monticello, MN nuclear plant.

Because of the many different nuclear reactor designs used in the early days of the nuclear industry, the true life span of a reactor that is up for license renewal will have to be determined on a case to case basis. The standard licensing agreements of 40 years were set by the Atomic Energy Commission without any regard of the expected life span of a reactor, which at that time was virtually unknown. Selection of 40 years as opposed to 20 years or 60 years was influenced more by the then current depreciation conventions for conventional power plants than by any technical or safety considerations. Of the 126 plants put into commercial operation thus far, 16 have shut-down or been decommissioned short of the 40 years. The reasons for the shut-downs have varied widely -- from a voter referendum (Rancho Seco, Sacramento, California) to design defects requiring extensive, expensive modifications (Indian Point #1, Buchanan, New York).[32]

Between 2000 and 2016 licenses of approximately 66 out of the nation's 111 reactors will expire.[32] How many old plants will actually apply for license extensions is not known – certainly not all of them. Although many are trouble free, they do not necessarily meet current standards for new plants. The cost of upgrading may be prohibitive, especially if the plant and its power output are small. At least three plants of the 66 are currently on the Nuclear Regulatory Commission's "watch list", Calvert Cliffs, Maryland; Nine Mile Point; New York and Zion, Illinois because of safety concerns.[33]

Utility operators of three recently shut nuclear reactors, Shoreham, New York,[34] Rancho Seco, California[35] and Fort St. Vrain, Colorado[36], are in the process of receiving approval to dismantle and decommission the units. All three utilities are studying the feasibility of converting the plants to burn natural gas as was done in the case of the Midland nuclear plant in Michigan.

The future of nuclear energy in the US remains murky. The industry has been heartened by growing concerns over contribution of fossil fuels to global warming, by the urging of the National Academy of Sciences to develop and test a new generation of reactors and by legislation sponsored by the Bush Administration to speed licensing of reactors. But public acceptance contingent on safety considerations and the unsolved problem of disposing of nuclear waste remain clear obstacles to rejuvenation of the industry. Although no new nuclear plant has been ordered since 1978, at least one utility, TVA, is considering the nuclear alternative in order to fill a need for new generating capacity in the next decade.[37]

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[4], the Quarterly Coal Report[38] and the *Annual Energy Review-1991*.[39]

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 feed stocks 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 is 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 is 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 (Figs. 1 & 2).

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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