Chapter 2

# Oil in the U.S. Economy

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## INTRODUCTION

Eighteen years after the first oil shock of the 1970s, oil continues to fuel much of America's economy. Oil is the major U.S. energy source supplying 42 percent of energy requirements in 1989. (See figure 2-l.) Energy use in the economy as a whole has grown from 74 quadrillion Btus (quads) in 1973 to 81.2 quads in 1989. However, there have been notable shifts in domestic use and production of oil.

Since 1970, domestic crude oil production has declined—falling from 9.6 million barrels per day (MMB/D) in 1970 to 7.6 MMB/D in 1989.[1] Imports have increased to meet domestic needs. In 1989 the United States imported 7.12 MMB/D of crude oil and oil products (about 41 percent of oil supplies), with 1.86 MMB/D coming from Persian Gulf producers. Over the same period, patterns of oil use in the U.S. economy changed as many users converted to other fuels and all sectors became more energy efficient.

This chapter profiles oil consumption and production in the United States and the changes in both over the past two decades. It concludes with a short summary of previous oil supply disruptions and the initial impacts of the Iraqi invasion of Kuwait and subsequent United Nations and allied actions.

## U.S. OIL CONSUMPTION

U.S. oil consumption was 17.2 MMB/D in 1989, down from a high of over 18.8 MMB/D in 1978. As a share of total energy use, oil provided about 42 percent of U.S. energy needs in 1989, compared to 49 percent in 1978. From 1979 to 1983, a period of economic downturn and very high oil prices, oil consumption declined 3.6 MMB/D. As oil prices fell and the economy began to expand, oil demand began to grow again and has averaged under 2 percent per year from 1984 to 1989. With the higher oil prices following the Iraqi invasion of Kuwait and the onset of a recession, oil product demand in 1990 was an estimated 2.4 percent lower than in 1989.[2]

There are five primary end-use applications for oil products: space and water heating, process steam and power generation, process heat, transportation, and feedstocks (raw materials used in manufacturing and processing). Oil products used for these applications include motor gasoline, distillate fuel oils, residual fuel oil, liquefied petroleum gases (LPG), jet fuel, and a variety of products grouped under the term "other petroleum products."

### *Petroleum Product Consumption*

Figure 2-2 shows the consumption of petroleum products from 1970 to 1989.

Motor gasoline is a light fuel used almost exclusively to power automobiles and light trucks. At present it has few widely available commercial substitutes. In 1989 motor gasoline constituted about 42 percent of total petroleum product use. Domestic refineries supply most gasoline needs, the rest is imported (about 360,000 barrels per day (B/D) in 1989).

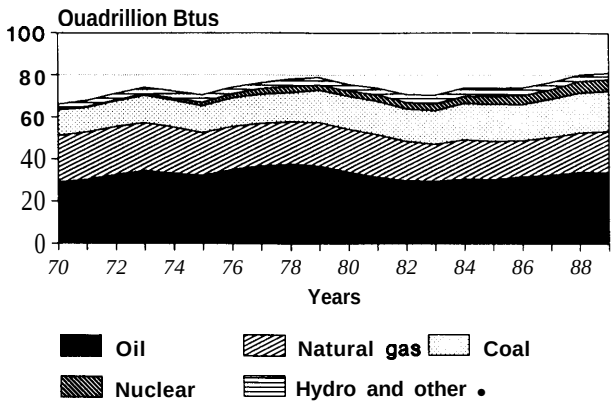
Consumption of motor gasoline hit an annual high of 7.4 MMB/D in 1978 and then declined to 6.54 MMB/D in 1982, owing to higher gasoline prices and substantial improvements in fleet fuel efficiency that more than offset increases in the total fleet and vehicle miles traveled. Lower gasoline prices and economic expansion in the mid-1980s contributed to renewed growth in gasoline demand from 1986 to 1989. Gasoline consumption reached 7.3 MMB/D in 1989.

Distillate fuel oils (Nos. 1, 2, and 4 fuel oils and diesel fuels) are used for diesel transportation fuel, for space heating in homes and in small commercial and industrial facilities, for industrial process heating, and for electricity generation. Distillates accounted for about 18 percent of 1989 oil use. Demand for distillates peaked at 3.4 MMB/D in 1978, dropped to 2.67 MMB/D in 1982, and then rose to 3.15 MMB/D in 1989. The United States imported about 300,000 B/D of distillates in 1989.

[1]Unless otherwise noted, information on U.S. energy and 0,1 use are drawn from U.S. Department of Energy, Energy Information Administration, ***Annual Energy Review 1989,*** DOE/EIA-0384(89) (Washington, DC: U.S. Government Printing Office, May 1990), hereinafter referred to as ***Annual Energy Review 1989.***

[2]U.S. Department of Energy, Energy Information Administration, *Annual Energy Review 1990,* DOE/EIA-0384(90) (Washington, DC: U.S. Government Printing Office, May 1991), table 61.

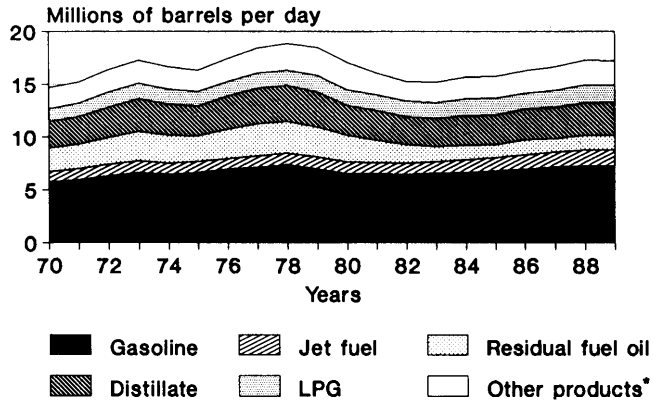
**Figure 2-1—U.S. Energy Consumption by Energy Source, 1970-89**




*Other includes grid-connected electric power from geothermal, wood, waste, wind, solar, and other sources.

SOURCE: Office of Technology Assessment, 1991, from data in U.S. Department of Energy, Energy Information Administration, *Annual Energy Review* 1989, DOE/EIA-0384(89) (Washington, DC: U.S. Government Printing Office, May 1990), table 3.

**Figure 2-2—Petroleum Products Supplied by Type, 1970-89**




* Other products include kerosene, aviation gasoline, petrochemical feedstocks, special naphthas, lubricants, wax, petroleum coke, asphalt, road oil, still gas, pentanes plus, and other miscellaneous products. From 1983 on crude oil burned as fuel is also included in this category.

SOURCE: Office of Technology Assessment, 1991, from data in U.S. Department of Energy, Energy Information Administration, *Annual Energy* Review 7989, DOE/EIA-0384(89) (Washington, DC: U.S. Government Printing Office, May 1990), table 60.

Residual fuel oil, the heavy oil left after the lighter products have been distilled in the refinery process, is primarily used as a boiler fuel by utilities and industry. A small amount is used as bunker fuel to power ships. Residual fuel oil competes directly with natural gas in industrial and electric generating facilities that can burn either gas or oil, and so its demand is highly tied to the relative price of natural gas. Use of residual fuel oil by utilities and industry has dropped substantially from a peak of 3.07 MMB/D in 1978. About 1.35 MMB/D of residual oil were used in 1989, or just under 8 percent of total oil demand.

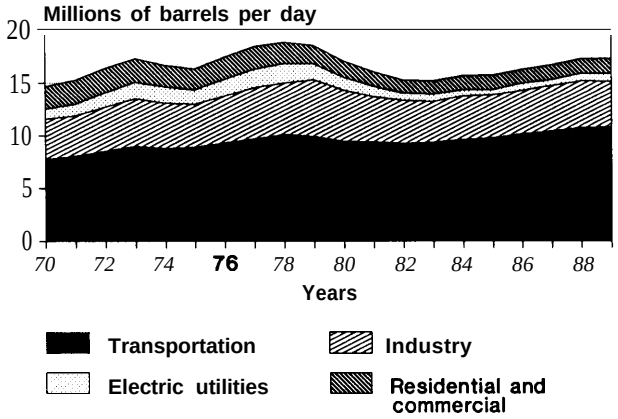
Changes in U.S. refinery capacity in the 1980s reduced the portion of residual fuel oil in refinery yields. Consequently, much of the residual oil consumption has been met by imports. Residual fuel oil imports were as high as 1.85 MMB/D in 1973, but have run at 500,000 to 700,000 B/D through most of the 1980s. Total imports of residual oil were 610,000 B/D in 1989, while exports were 213,000 B/D.

Jet fuel demand was about 1.49 MMB/D in 1989, or about 8.6 percent of total petroleum product use. Demand included commercial, military, and general aviation uses. Following a 3-year drop in demand in 1980-83, jet fuel consumption has risen over 440,000 B/D since 1984. Improved economic conditions, airline fare competition, and travel incentives have boosted passenger miles flown. Imports of jet fuel were 102,000 B/D in 1989.

Liquefied petroleum gases include ethane, propane, butane, and other gases from natural gas processing plants as well as liquefied refinery gases (ethylene, propylene, butylene, and isobutylene) produced from crude oil. Most LPG is derived from crude oil, but some. is derived from natural gas. LPG is used as a fuel in the residential and commercial sectors and as a fuel and feedstock in the industrial sector. In 1989 LPG made up 1.66 MMB/D or about 9.6 percent of oil product demand, the highest level of demand in the past 20 years. LPG imports totaled about 180,000 B/D in 1989.

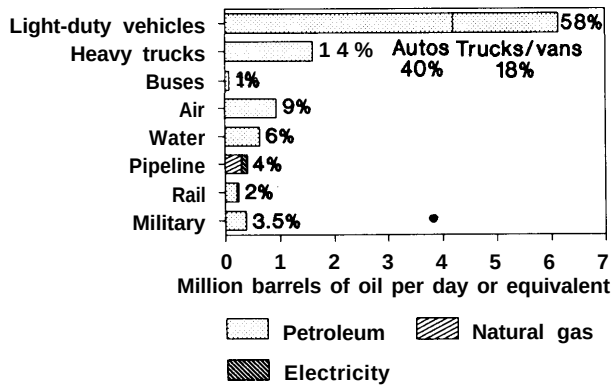
Demand for other petroleum products was 2.26 MMB/D in 1989. This category includes petrochemical feedstocks, kerosene, asphalt and road oil, lubricants, waxes, and other oil products. Demand for these products is closely tied to economic conditions in the industrial sector and declined from a high of 2.67 MMB/D in 1979 to a low of 1.86 MMB/D in 1982. This category currently represents about 13 percent of total petroleum product demand. Imports were about 270,000 B/D in 1989.

**Figure 2-3—U.S. Oil Use by Sector, 1970-89**




SOURCE: Office of Technology Assessment, 1991, from data in U.S. Department of Energy, Energy Information Administration, *Annual Energy* Review 1989, DOE/EIA-0384(89) (Washington, DC: U.S. Government Printing Office, May 1990), table 61.

**Figure 2-4-Energy Consumption in the U.S Transportation Sector, 1989**




SOURCE: Office of Technology Assessment, 1991, from data in Stacy C. Davis and Patricia S. Hu, *Transportation Energy Data Book: Edition 11, ORNL-6649* (edition 11 of ORNL-5198) (Oak Ridge, TN: Oak Ridge National Laboratory, January 1991).

## *Oil Consumption by Sector*

Demand for oil in each of the major end-use sectors—transportation, commercial, residential, industrial, and electric utilities—is generally sensitive to price, but the sectors are not equally responsive to changes in price. Patterns of oil consumption and relative shares of demand for the major sectors for 1970 to 1989 are shown in figure 2-3. The largest oil users are the transportation and industrial sectors, which together accounted for 88 percent of total oil demand in 1989. During the late 1980s oil consumption in these sectors grew due to lower oil prices and renewed economic growth, and because there were few commercially available substitutes for petroleum-derived motor vehicle fuels and industrial feedstocks. More detail on oil use in all sectors can be found in chapter 3.

### Transportation

The transportation sector encompasses highway, air, rail, water, and pipeline transport and all modes of military transportation.[3] This sector alone accounts for almost 63 percent of the Nation's total oil consumption and about 27 percent of total energy demand. At 10.85 MMB/D in 1989, transportation sector oil demand was the highest it has ever been. Consumption has grown more than 1 MMB/D since oil prices dropped sharply in 1986. Oil supplies over 95 percent of transportation energy needs with natural gas and electricity accounting for the remainder. (See figure 2-4.) The primary petroleum products used are motor gasoline, diesel (distillate) fuel, jet fuel and other aviation fuels, and residual fuel oil for marine transportation.

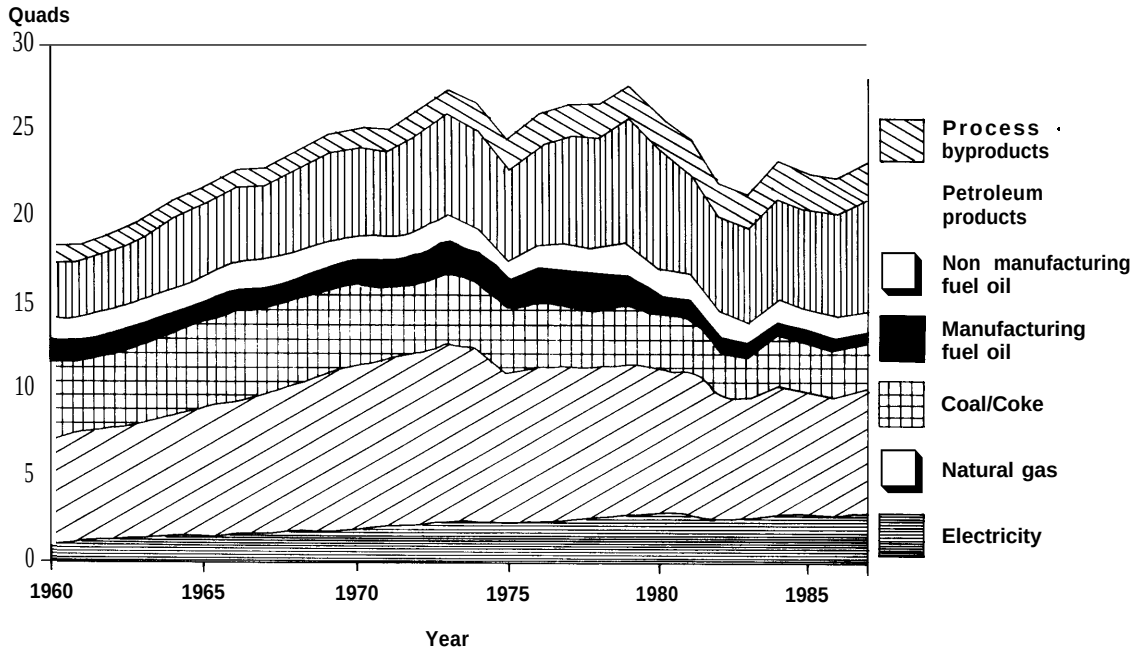
The major factors influencing transportation demand for motor gasoline and distillate fuels include fleet size (total number of vehicles), fleet mix (kinds of vehicles), fleet fuel efficiency (miles per gallon for all vehicles in the fleet), new vehicle fuel efficiency (miles per gallon for new cars and trucks), total number of vehicle miles traveled, and the rate of replacement of old vehicles by new vehicles.

Economic trends, such as changes in gross national product, personal income, or demographic patterns, also affect petroleum product consumption in the transportation sector.[4] For example, a surge in new

[3]Off-highway transportation for agriculture, construction, and other industrial activities is attributed to the industrial sector.

[4]Demographic influences can push transportation demand in different directions. For example, an increase in the number of drivers tends to increase vehicle miles. As the average age of drivers increases, vehicle miles are expected to decline. However, as the baby boomers move through the family-forming years, a shift in preference to larger ears within that group could somewhat offset overall increases in vehicle efficiencies.

**Figure 2-&Energy and Oil Use in the industrial Sector**




**SOURCE: Office of Technology Assessment, 1991, from data in Gas Research Institute, "Industrial Natural Gas Markets: Facts, Falacies and Forecasts," March 1989.**

car sales in 1985-86, prompted by an increase in disposable personal income and various dealer incentives, boosted average new vehicle fuel efficiency by twice the anticipated rate. Indeed, shifts in any of the foregoing factors could affect transportation demand by up to several hundred thousand barrels per day, which is a significant portion of any incremental demand met by imports.

## Industrial Sector

The industrial sector includes manufacturing, agriculture, forestry, fishing, construction, mining, and oil and gas production. Petroleum supplies about 36 percent of total industrial sector energy needs (excluding energy lost in generation and transmission of electric power sold to the industrial sector). All together, industrial sector activities consume about 25 percent of the total oil demand. Feedstocks comprise about one-half of industrial oil use.

Industrial oil demand has ranged between about 25 and 33 percent of total petroleum product consumption in the past two decades. It reached a high of 5.34 MMB/D in 1979, slid to 3.85 MMB/D in 1983, and grew to 4.26 MMB/D in 1989.

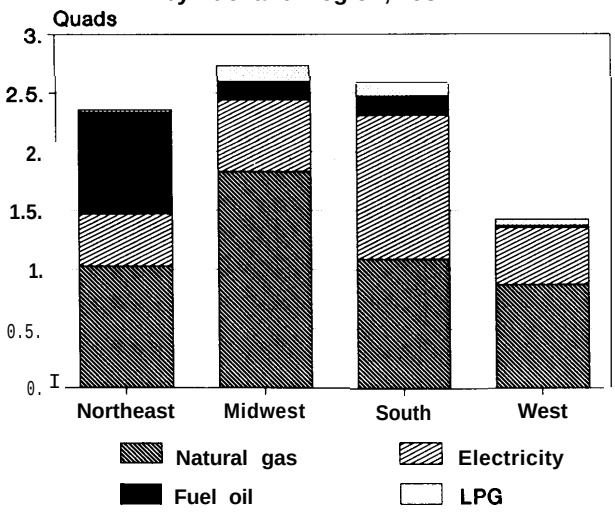
The applications and mix of oil products used in the industrial sector are diverse (figure 2-5). Distillate and residual fuel oils, liquefied petroleum gas, petrochemical feedstocks, and asphalt and road oil make up a large share of industrial oil product demand. Oil products are burned for steam and power generation and process heat, and are used as fuel for industrial and agricultural equipment and as feedstocks for the manufacture of other products.

Industrial oil demand is sensitive to general economic trends. Feedstock demand, the largest category of industrial oil use, generally follows economic growth. Oil use in dual-fuel industrial boilers is tied to the relative prices of oil and natural gas.

## Residential and Commercial Sectors

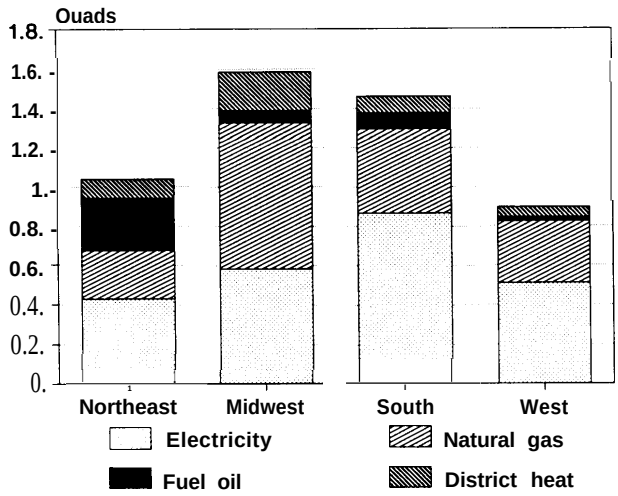
The residential and commercial sectors together consumed about 8 percent of all oil used in the U.S. economy in 1989. From 1973 to 1989, oil demand in

**Figure 2-6-Residential Energy Consumption by Fuel and Region, 1987**




SOURCE: Office of Technology Assessment, 1991, from data in U.S. Department of Energy, Energy Information Administration, *Household Energy Consumption and Expenditures 1987, Part 2: Regional Data,* DOE/EIA-0321 *(87)/2* (Washington, DC: U.S. Government Printing Office, January 1990).

**Figure 2-7-Commercial Sector Energy Consumption by Fuel and Region, 1986**




SOURCE: Office of Technology Assessment, 1991, from data in U.S. Department of Energy, Energy Information Administration, Non-*residential Buildings Energy Consumption Survey: Commercial Buildings Consumption and Expenditures 1986,* DOE/EIA-0318(86) (Washington, DC: U.S. Government Printing Office, May 1989), table 11.

the residential and commercial sectors declined from 2.25 to 1.4 MMB/D, mostly because of energy efficiency gains and conversions to other fuels. Oil use actually reached a low of 1.24 MMB/D in 1982 before beginning a gradual increase.

The residential sector consists of single- and multifamily homes, apartments, and mobile homes. About 18 percent of all housing units or 16.4 million residential units use oil as a primary heating fuels Residential demand is about 5 percent of total demand and consists mostly of space and water heating—mainly in the Northeast. (See figure 2-6.) A map of census regions can be found in the appendix. Residential fuels are primarily distillate fuel oil and LPG. The number of American homes heated by oil products has generally been declining since the 1960s, although the 1980s saw a slight increase in oil heating in areas where electric heat is expensive and natural gas availability limited.

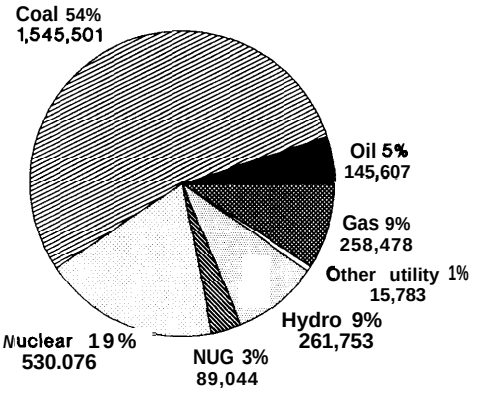
The commercial sector includes offices, stores, and other nonindustrial businesses; educational, health care, and religious institutions; and Federal, State, and local governments. The commercial sector accounts for 3 percent of total oil use. About half of commercial demand is for distillate and the remaining half about equally split between residual fuel oil and LPG. About 18 percent of U.S. commercial buildings, or 750,000 buildings depend on oil products for heat. Commercial oil use is concentrated in the Northeast and in rural and suburban areas of the South and Midwest that have no local natural gas service. (See figure 2-7.)

Growth in oil demand in the residential and commercial sectors primarily reflects increases in the amount of building square footage heated and annual temperature trends. It is tempered by changes in the energy efficiency of new and existing buildings and in their heating equipment. Residential and commercial oil consumption is much less sensitive to price than consumption in other sectors, and shifts in fuel preferences take place slowly. Greater domestic economic activity is expected to increase commercial floor space and thus increase commercial demand. The amount of residential floor space will also grow, but at a slower rate.

Expectations of stable, low oil prices and economic growth in localities not served by natural gas service—such as suburban areas in the Northeast and the Midwest---could favor more use of oil for space

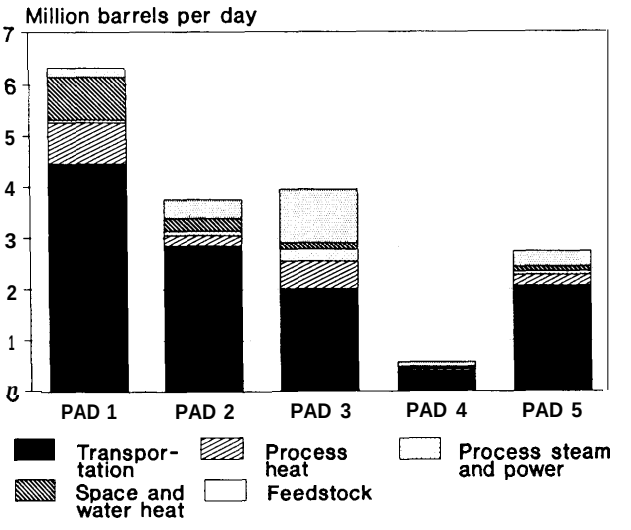
[5]U.S. Department of Energy, Energy Information Administration, *Household Energy Consumption and Expenditures 1987, Part 2, Regional Data,* DOE/EIA-0321(87)/2 (Washington, DC: U.S. Government Printing Office, January 1990), table 2.

**Figure 2-8—U.S. Electricity Generation by Fuel Source, 1989**




SOURCE: Office of Technology Assessment, 1991, from data in North American Electric Reliability Council, 1990 *Electricity Supply and Demand for 1990-1999* (Princeton, NJ: North American Electric Reliability Council, December 199o), app. B.

**Figure 2-9-Oil Use by Application and Region, 1989**




SOURCE: Office of Technology Assessment, 1991, from data in Paul D. Holtberg and David O. Webb, "The Potential for Natural Gas To Displace Oil in Response to the Middle East Crisis and the Implications for the GRI R&D Program," *Gas Research Insights,* Gas Research Institute, November 1990.

heating in preference to other fuels. Continued low oil prices could add to the stock of new residential and commercial buildings heated by oil, delay conversions from oil to competing fuels, and lead to the deferral of major investments in conservation.

### Electric Utilities Sector

The electric utility sector includes both public and private utilities that generate and or sell electricity, primarily to the public.[6] Electric utilities burned 740,000 B/D of oil products in 1989, about 4.3 percent of total oil consumption. Oil-fired generation is concentrated in the Northeast, California, Florida, and Hawaii .[7] Almost 90 percent of oil used by electric utilities is residual fuel oil. Electric utilities account for about 36 percent of U.S. energy demand, but only about 5.7 percent of utility energy needs are met by petroleum products. (See figure 2-8.)

Demand for oil for power generation has been declining since the 1970s and is now less than half what it was at its peak of 1.75 MMB/D in 1978. The reduction in oil use can be attributed to fuel switching (mostly to natural gas) in dual-fuel capable facilities and the replacement or substitution of older oil-fired capacity with new coal, nuclear, and natural gas units. Demand for oil for power generation is tied to the relative prices of oil and competing fuels, generating capacity needs and availability, weather conditions, and the seasonal availability of natural gas. At present oil and natural gas prices, oil-fired units are primarily used as peaking capacity or when other (less expensive) capacity is unavailable. A sharp drop in oil prices, steep growth in peak electricity demand, or a tightening of natural gas supplies could spur an increase in utility oil use.

## *Oil Use by Application*

Figure 2-9 shows how oil was used for transportation, feedstocks, process steam and power generation, space and water heating, and process heat. It also shows the relative shares of these end-use applications in 1989.[8] There are regional variations in oil use, but transportation is the dominant category in all regions.

[6]Fuel consumption in industrial and Commercial self. generation and cogeneration is usually attributed to those sectors, although some of these generators sell power to electric utilities.

[7]Hawaii and many remote communities in Alaska are almost exclusively dependent on oil for power generation; but the amounts used are small compared to other States.

[8]Information on end-use applications and consumption are from Paul D. Holtberg and David O. Webb, "The Potential for Natural Gas to Displace Oil in Response to the Middle East Crisis and Implications for the GRI R&D Program," *Gas Research Insights,* Gas Research Institute, November 1990.

**Table 2-1—U.S. Oil Consumption by Application and Region, 1989**
**(thousand barrels per day)**

| Application | PAD 1 | PAD 2 | PAD 3 | PAD 4 | PAD 5 | Total |
|---|---|---|---|---|---|---|
| Space & water heating | 826 | 254 | 140 | 29 | 96 | 1,345 |
| Transport | 4,462 | 2,856 | 2,014 | 401 | 2,063 | 11,796 |
| Process steam & power generation | 797 | 197 | 528 | 42 | 208 | 1,772 |
| Process heat | 47 | 84 | 234 | 19 | 67 | 450 |
| Feedstock | 204 | 366 | 1,019 | 84 | 290 | 1,962 |
| Total | 6,335 | 3,757 | 3,935 | 575 | 2,724 | 17,325 |

SOURCE: Office of Technology Assessment 1991, from data in Paul D. Holtberg and David O. Webb, "The Potential for Natural Gas To Displace Oil in Response to the Middle East Crisis and the Implicationsforthe GRI R&D Program: Gas Research Insights, Gas Research institute, November 1990.

`Combiningallsectors, almost 70percentoftheoil used in the United States in 1989—ll.8 MMB/D—was used to move people and things. Gasoline and diesel fuel for cars, trucks, buses, and motorcycles made up over two thirds of total transportation demand. Off-highway uses, including commercial and military aircraft, ships, trains, mining and construction equipment, and farm vehicles, used about 3 MMB/D.[9] About half of off-highway demand was for jet fuel.

Regional oil consumption for transportation usually reflects population. Transportation's share of total oil demand varies among regions from 51 percent in the gulf coast Petroleum Administration for Defense District (PAD 3) to 76 percent in the west coast (PAD 5). A map of PAD districts can be found in the appendix.

More than 1.96 MMB/D of petroleum feedstocks were supplied in 1989, about 11 percent of total oil demand. Since this demand is substantially all for oil refineries and petrochemical plants, more than half of feedstock uses were in PAD 3. Significant amounts of feedstocks were also used in the west coast, PAD 5.

Oil products used for process steam and power generation totaled almost 1.8 MMB/D in 1989, or about 10 percent of total oil use. Consumption is split almost equally between the industrial and electric utility sectors. Strong regional use patterns are evident, with over 85 percent of utility demand in the east coast, PAD 1, and over half of industrial demand in the gulf coast, PAD 3. Industrial consumption is concentrated in the petrochemical and refining industries; however, a significant share of this demand is met by waste products, such as still gas.

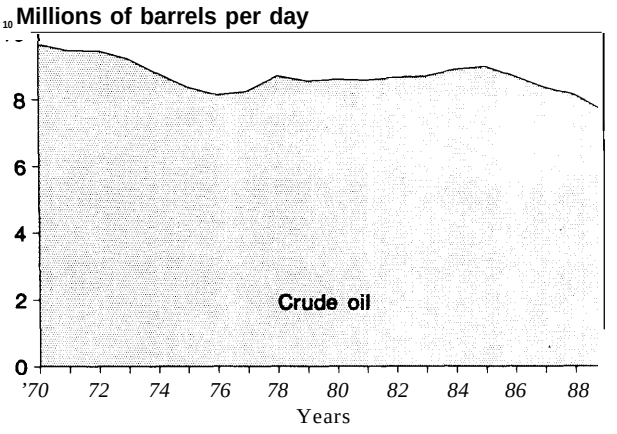
Space and water heating consumed 1.3 million barrels of oil in 1989 or just under 8 percent of the total. About 90 percent of consumption was distillate fuel oil for space heating. LPG, kerosene, and residual fuel oil account for the remaining products used. Space heating use is highest on the east coast,[10] PAD 1, and in the Midwest, PAD 2, as shown in table 2-1. Together these regions account for 80 percent of space and water heating use.

About 450,000 B/D of oil products were burned to provide process heat. This represents slightly just under 3 percent of total oil demand in 1989. Petrochemical plants and refineries account for much of

[9]Off-highway 0,1 consumption by farm vehicles and mining and construction equipment is generally attributed to the industrial sector rather than the transportation sector in tallying sectoral energy use.

[10]Half the Consumption in PAD 1 is in just four States: New York, New Jersey, Massachusetts, and Pennsylvania.

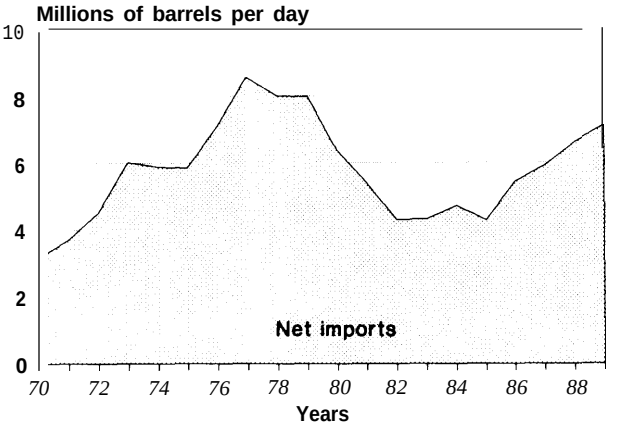
**Figure 2-l&U.S. Crude Oil Production, 1970-89**




*includes lease condensate

SOURCE: Office of Technology Assessment, 1991, from data in U.S. Department of Energy, Energy Information Administration, *Annual Energy Review* 7989, DOE/EIA-0384(89) (Washington, DC: U.S. Government Printing Office, May 1990), table 50.

**Figure 2-1 l—Net U.S. Oil Imports, 1970-89**




SOURCE: Office of Technology Assessment, 1991, from data in U.S. Department of Energy, Energy Information Administration, *Annual* Energy Review 1989, DOE/EIA-0384(89) (Washington, DC: U.S. Government Printing Office, May 1990), table 50.

this consumption, and waste oils meet a significant portion of this demand. About half of process heat applications are located in the gulf coast, PAD 3.

## DOMESTIC PRODUCTION

U.S. crude oil production reached an all time high of 9.6 MMB/D in 1970. This was followed by 6 years of declining output until higher prices and new Alaskan North Slope production reversed this trend. Oil production climbed back to 8.97 MMB/D by 1985 (see figure 2-10). In 1986, in the wake of a steep drop in world oil prices, U.S. production began to decrease again. By 1989, domestic crude oil production was 7.63 MMB/D-l.34million barrels less than in 1985. The production of natural gas plant liquids, which hit a high of 1.74 MMB/D in 1973-74, was at 1.55 MMB/D in 1989, its lowest level in 20 years.

Oil exploration activities are a primary key to maintaining reserve additions to sustain production. Exploration activities surged in the late 1970s because of high oil prices and the expectation that even higher world oil prices would prevail. In 1981, as a result of this rapid industry expansion, the main indicators of exploratory activity reached record peaks-3,970 rotary rigs operating (monthly average), 681 seismic crews active (weekly average), and a total of over 17,500 exploratory wells completed.[11] When world oil prices began to slide, domestic exploration activities fell too. The free fall in world oil prices in 1986 further devastated domestic exploration and development. The number of wells drilled plunged to 201, and rotary rigs active totaled only 964-less than half the number operating a year before.[12] Exploratory wells completed dropped to 7,150. As oil prices began to firm up, albeit at much lower real levels in the late 1980s, there was a modest upswing in domestic exploration and development investment. However, key indicators still hit a 40-year low in 1989—869 rotary rigs in operation, 132 seismic crews active, and about 5,220 exploratory wells completed. [13] The drop in activity brought about a shrinking in the infrastructure of the domestic oil

[11] *Annual Energy Review* 1989, supra note 1, p. 89, tables 41 and 42.

[12] For further discussion of the impacts on the domestic petroleum industry, see U.S. Congress, Office of Technology Assessment, U.S. *Oil Production: The Effect of Low Oil Prices— Special Report, OTA-E-348* (Washington, DC: U.S. Government Printing Office, September 1987).

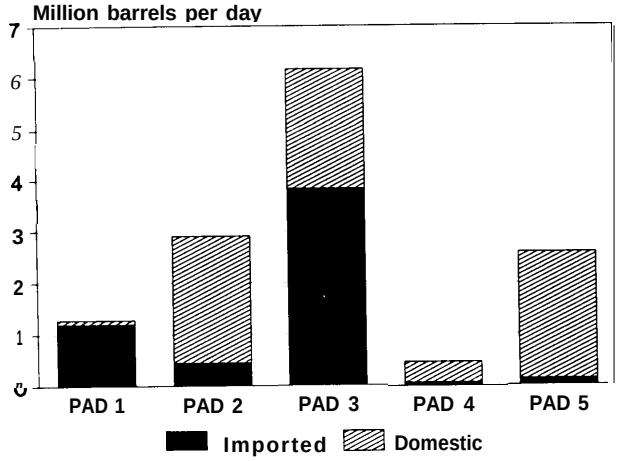
[13] The higher oil Prices in 1990 brought about a brief upswing in exploration indicators. According to preliminary information released by the American Petroleum Institute, domestic oil production in the first half of 1991 was up by 0.6 percent over 1990, reversing the recent pattern of declining output. API attributed the production rise to increased exploration and production activity in 1990, better economic conditions for producers, and technology improvements. See "Oil Demand Falls to Lowest Level Since 1983," *The Energy Daily,* July 18, 1991, p. 4.

industry—a reduction in the availability of equipment, skilled workers, and supporting manufacturing and maintenance services capability that could slow any future expansion of domestic exploration.

## OIL IMPORTS

Imports fill the gap between domestic production and demand. In 1970, net oil imports totaled 3.16 MMB/D and climbed to reach 8.56 MMB/D (46 percent of U.S. oil consumption) in 1977 (see figure 2-11). As oil demand dropped in response to very high oil prices, net import levels declined to 4.29 MMB/D in 1985 (27 percent of oil use). Lower world oil prices and rising demand drove net imports of crude oil and petroleum products to 7.12 MMB/D in 1989 (41 percent of domestic consumption). Gross oil imports in 1989 were 7.98 MMB/D and exceeded domestic crude production for the first time since 1977. Imports of crude oil predominate, but imports of petroleum products have been increasing too.

**Figure 2-12 Source of Crude Oil Processed by U.S. Refineries, 1989**
**(by region)**




SOURCE: Office of Technology Assessment, 1991, from data in Paul D. Holtberg and David O. Webb, 'The Potential for Natural Gas To Displace Oil in Response to the Middle East Crisis and the Implications for the GRI R&D Program," Gas *Research Insights, Gas* Research Institute, November 1990.

The United States imported a total of 1.86 MMB/D of crude oil, natural gas liquids, and refined products from the Persian Gulf nations in 1989—more than 1.5 MMB/D more than in 1983.[14] Persian Gulf imports made up about 11 percent of total U.S. consumption and and 23 percent of gross imports for 1989. For the first half of 1990, Persian Gulf imports were running slightly ahead of those of the previous year. In the first quarter of 1990, U.S. imports of crude oil and refined products totaled 8.4 MMB/D. Of this, 2.3 MMB/D came from Persian Gulf countries representing about 27 percent of our imports and about 15 percent of Persian Gulf production.[15] By the end of 1990, annual net imports were about 7.1 MMB/D, Persian Gulf imports were about 2 MMB/D.

### *U.S. Regional Import Dependence*

Under current oil supply and distribution patterns, there are clear regional dependencies on imported crude and refined products. Any interruption in oil imports would likely be felt first and most severely in those regions that are most dependent.

In 1989, the United States imported 5.8 MMB/D of crude oil. Most crude oil imports enter the country through east coast (PAD 1) and gulf coast (PAD 3) ports. Figure 2-12 shows the origins of refinery throughput by region. Imports provide over 95 percent of refinery throughput in the east coast and about 60 percent for gulf coast refineries. The west coast (PAD 5) and Rocky Mountain (PAD 4) regions are largely self-sufficient, producing and refining their own oil. Domestic crude supplies the largest share of refinery throughput in the Midwest (PAD 2); most of this crude comes from PAD 3, however.

Imports of petroleum products totaled 2.2 MMB/D in 1989. This was considerably less than the 3 MMB/D imported in 1973; however, much of the difference reflects a sharp drop in residual oil. U.S. refiners exported 717,000 B/D of petroleum products in 1989, the highest level ever. Netting out these exports, the United States used about 1.5 MMB/D of imported products. Over 95 percent of imported petroleum products are used in the east coast (PAD 1).

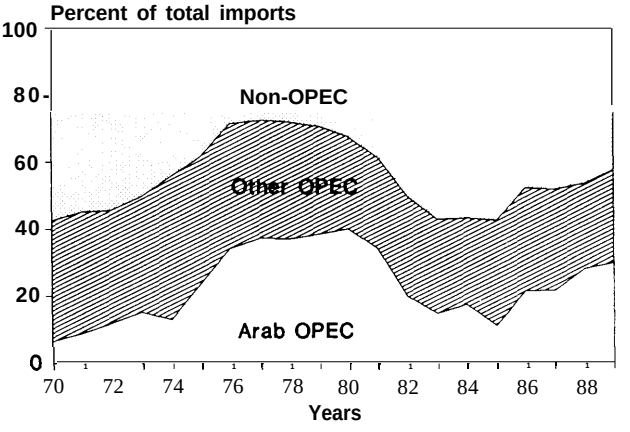
### *Sources of Imported Oil*

Over the past 20 years, the United States has diversified its sources of imported oil, as shown in figure 2-13. The major U.S. oil suppliers include Saudi

[14]U.S. Department of Energy, Energy Information Administration, *International Petroleum Statistics Report,* DOE/EIA-0520(91/02), February 1991, table 3.6.

[15]Gas Research Institute, supra note 8.

**Figure 2-13-Percent of U.S. Oil Imports by Source, 1970-89**




SOURCE: Office of Technology Assessment ,1991, from data in U.S. Department of Energy, Energy Information Administration, *Annual Energy Review* 1989, DOE/EIA-0384(89) (Washington, DC: U.S. Government Printing Office, May 1990), table 56.

Arabia, Venezuela, Canada, Nigeria, and Mexico. In 1989, imports from the Organization of Petroleum Exporting Countries (OPEC) made up 57.6 percent of total net imports, the highest level since 1981, but less than in 1976 through 1980 when OPEC's share was more than 70 percent.[16] Imports from OPEC countries have increased since 1985, much of the additional oil coming from Saudi Arabia. In 1981 Arab OPEC countries accounted for 54 percent of U.S. net imports. This share dropped to 11 percent in 1985, but increased to 29 percent in 1989.[17]

## OIL SUPPLY DISRUPTIONS

Before the August 1990 Iraqi invasion of Kuwait and the subsequent United Nations sanctions, the world had weathered a number of oil supply disruptions. In the past 20 years there have been three serious oil supply disruptions resulting in the loss of significant shares of crude oil production for periods of several months. These included the Arab oil embargo (1973), the Iranian revolution (1978-79), and the outbreak of the Iran-Iraq war (1980). Many industry analysts would also add the 1986 plunge in world oil prices to the list of oil crises, because of its devastating impact on the economic viability of the oil industry in high-cost regions, including the United States. In addition to these major disruptions there were smaller disruptions caused by wars, political unrest, and accidents. As shown in table 2-2, about half of these disruptions lasted 5 months or more. The two major oil crises of the 1970s, however, lasted under 6 months. The largest disruption was the production loss of 3.7 MMB/D following the Iranian revolution in 1978. These shortfalls were met to varying degrees by conservation induced by higher prices, the drawdown of commercial inventories, and increased production from excess capacity.

An analysis of these disruptions by the Interagency Working Group review of Strategic Petroleum Reserve (SPR) size options concluded:[18]

- Thirteen disruptions resulted in the loss of 1 percent or more of consumption. A similar disruption today would amount to about 500,000 B/D (using the "free world" oil market). The group found this to be "mathematically equivalent to a 30 percent chance of a disruption of at least this size in any given year. "
- Five disruptions involved the loss of 5 percent or more of consumption—roughly equivalent to 2.5 MMB/D of oil at present. This equates to a 13-percent chance of this size disruption in a given year.
- Overall, there is a 10-percent likelihood (plus or minus 5 percent) of a modest supply disruption of 8 to 11 MMB/D occurring between 1995 and 2010. This estimate is subject to considerable uncertain y after 2000 because of the large number of unknown factors involved—e.g., global oil prices, oil demand, new technologies, new oil discoveries, political and military developments—making the assessment perhaps better characterized as "informed speculation."
- The United States is better equipped now to deal with an oil supply disruption than in 1979 because of the larger unused world oil production capacity at present (an estimated 5 to 7 MMB/D in 1990) and the strategic petroleum stock pro-

[16]Current OPEC members are Algeria, Ecuador, Gabon, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, United Arab Emirates, and Venezuela.

[17]Arab OPEC Countries consist of Algeria, Iraq, Kuwait, Libya, Qatar, Saudi Arabia, and the United Arab Emirates.

[18]Interagency Working Group, *Strategic Petroleum Reserve: Analysis of Size Options*, DOE/IE-0016 (unclassified report), February 1990, p. IV-2.

## Table 2-2—World Oil Supply Disruptions, 1951-89

| Dates | Event | Size of supply shortfall (MMB/D) | Duration (months) | World oil consumption (MMB/D) | Percent of world consumption | Percent change in world oil prices |
|---|---|---|---|---|---|---|
| March 1951–October 1954 | Iranian fields nationalized | 0.7 | 44 | 13,2 | 5.30 | +12.9 |
| November 1956-March 1957 | Suez War | 2.0 | 4 | 17.5 | 11.43 | –1.6 |
| December 1966-March 1967 | Syrian transit fee dispute | 0.7 | 3 | 34.3 | 2.04 | NC |
| June 1967–August 1967 | Six Day War | 2,0 | 2 | 40.0 | 5.00 | NC |
| July 1967-October 1968 | Nigerian Civil War | 0.5 | 15 | 40.1 | 1.25 | -37 |
| May 1970-January 1971 | Libyan price controversy | 1,3 | 9 | 48.0 | 2.71 | +25 |
| April 1971-August 1971 | Algerian-French nationalization struggle | 0.6 | 5 | 50.2 | 1.20 | NC |
| March 1973–May 1973 | Lebanese political conflict | 0. 5 | *2* | 58.2 | 0.86 | *+26* |
| October 1973–March 1974 | October Arabr Israelie War | 1.6 | *5* | 58,2 | 2,75 | *+276* |
| April 1976-May 1976 | Civil War in Lebanon | 0.3 | *2* | 60.2 | 0.50 | *NC* |
| May 1977 | Damage at Saudi oilfield | 0.7 | 1 | 62.1 | 1.13 | *NC* |
| November 1978–April 1979 | Iranian Revolution | 3,7 | 6 | 65.1 | 5.68 | +82.4 |
| October 1980-January 1981 | Outbreak of Iran-Iraq War | 3.0 | 3 | 60.4 | 4.97 | *+9.8* |
| July 1988-November 1989 | U.K. Piper Alpha offshore platform explosion | 0.3 | 2 | 49.8 | 0,60 | *+23.4* |
| December 1988-March 1989 | U.K. Fulmer floating storage vessel accident | 0.2 | 4 | 51.6 | 0.39 | +7.9 |
| April 1989-June 1989 | U.K. Cormorant offshore platform | 0.5 | *2* | 51.6 | 0.97 | –17.48 |

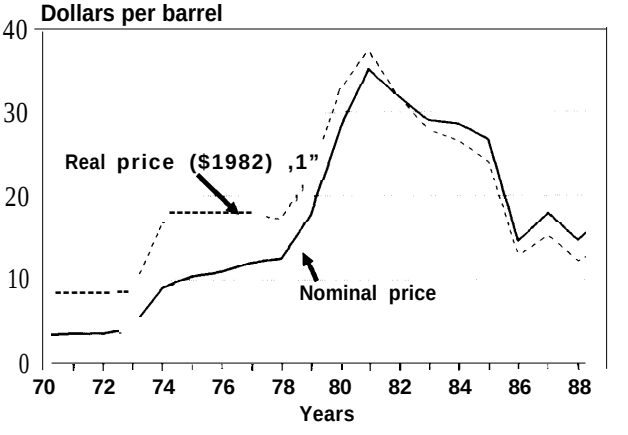
NC = no change

SOURCE: Office Of Technology Assessment 1991, from information in Interagency Working Group, Strategic Petroleum *Reserve: Analysis of Size Options,* DOE/IE-0016 (unclassified report), February 1990, tables IV-I and IV-2.

gram of International Energy Agency (IEA) member countries (with holdings of over 1 billion barrels at the end of 1989).

The economic impacts of disruptions often outlasted the duration of the actual supply losses. The effects on oil prices and on the economies of oil-consuming nations were, in the opinion of some, out of proportion to the actual shortfall.[19] The impacts were amplified by the interaction of government policies, and consumer and supplier fears as played out in spot markets. Figure 2-14 shows oil price trends in nominal and 1982 dollars from 1970 to 1989. As noted in the 1984 OTA assessment, the sharp price increases persisting after the oil shocks of the 1970's were, in themselves, effectively a type of oil supply curtailment.

**Figure 2-14 Crude Oil Refiner Acquisition Cost, 1979-89 (composite nominal and real prices, 1982 dollars)**




SOURCE: Office of Technology Assessment. 1991. from data in U.S. Department of Energy, Energy Information Administration, *Annual Energy* Review 1989, DOE/EIA-0384(89) (Washington, DC: U.S. Government Printing Office, May 1990), table 68.

## THE PERSIAN GULF CRISIS 1990-91[20]

On August 2, 1990 Iraqi troops occupied Kuwait. The invasion came some two weeks after Iraqi President Saddam Hussein had accused Kuwait of overproducing its OPEC quota and pushing world oil prices down.

The initial charges, which surfaced publicly on July 17, were followed by claims that Kuwait was draining Iraqi oil at wells situated near the border and by veiled threats that it would take action if matters were not resolved. Shortly thereafter, Iraq began moving troops to its border with Kuwait. Other Arab States began what proved to be unsuccessful efforts to mediate the dispute.

These actions were promptly reflected in world oil markets. On July 17, 1990, West Texas Intermediate (WTI) crude oil futures closed at $17.69/barrel (bbl), up slightly from the previous week in anticipation of an expected OPEC agreement to raise oil prices .21 At the July 27th OPEC ministers meeting, agreement was reached on a production ceiling of 22.5 MMB/D and a target price of $21/bbl. By July 30th WTI, the benchmark U.S. crude oil, closed at $21.59/bbl on the futures exchange.

Immediately following the invasion, President Bush froze Iraqi and Kuwaiti assets in the United States, and banned trade and other transactions with Iraq. The House and Senate also responded with legislation to support the executive order. The United Nations Security Council passed Resolution 660 calling for Iraqi withdrawal from Kuwait. The European Community and Japan joined the boycott on oil imports from Iraq and Kuwait. On August 6, the U.N. Security Council passed Resolution 661 prohibiting U.N. member nations from importing any Iraqi or Kuwaiti products or transferring funds to either nation.

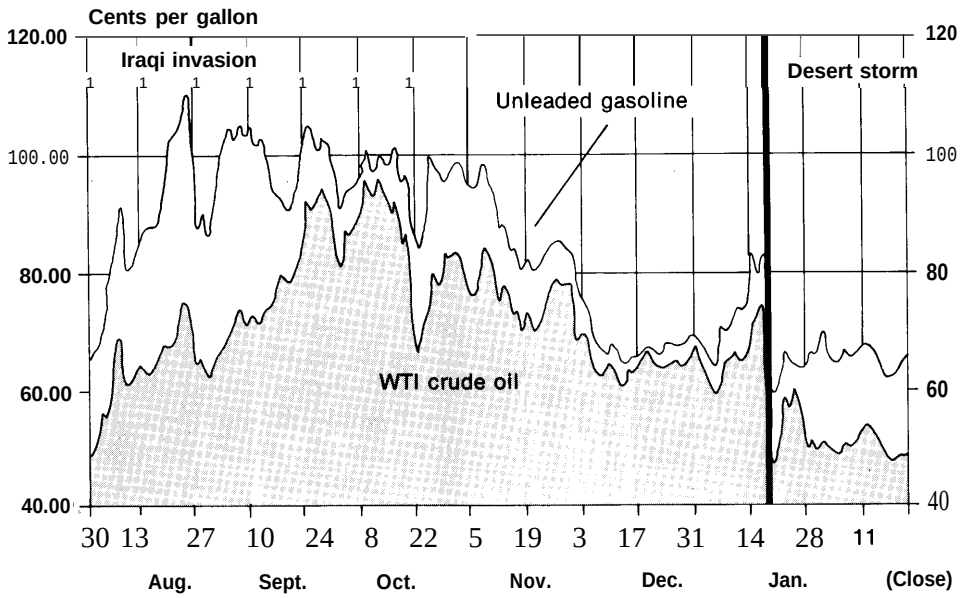
Oil prices rose to $23.71/bbl on news of the invasion and at the end of one week, crude oil prices rose to $28.05/bbl on world markets. The crude price rise quickly translated into higher gasoline prices at the pump. (See figure 2-15.)

[19] See for example, the extensive discussion of the impacts of the oil disruptions in the 1970s and 1980s in National Petroleum Council, *Factors Affecting U.S. Oil and Gas Outlook,* February 1987.

[20] Details on actions following Iraqi invasion of Kuwait are from Clyde R. Mark and Renee Stasio, "Iraq-Kuwait Crisis: A Chronology of Events, July 17, 1990-February 7, 1991," Congressional Research Service, Feb. 8, 1991, and from U.S. Department of Energy, Energy Information Administration, *Daily Energy Situation Analysis Reports,* August 19 90-March 1991.

[21] "OGJ Newsletter," Oil *and Gas Journal,* vol. 88, July 23, 1990.

**Figure 2-15-Crude Oil and Unleaded Regular Gasoline Prices, July 1990 to February 1991**




SOURCE: Office of Technology Assessment, 1991, from data in U.S. Department of Energy, Energy Information Administration, "Daily Energy Situation Analysis Report," various issues August 1990- March 1991.

Within a week of the invasion, the United States and other nations began to mobilize forces to aid in the defense of Saudi Arabia. On August 12, the President committed U.S. naval forces to halt all Iraqi imports and exports. Iraq announced its annexation of Kuwait and interned thousands of U.S. and other nationals in Iraq and Kuwait. On August 25, the U.N. Security Council authorized navies deployed in the Middle East to use force to enforce the embargo against Iraq. By August 22, crude oil prices closed at $31.22/bbl, the highest level in 5 years. On August 29, OPEC members agreed to increase production quotas to make up for the loss of Iraqi and Kuwaiti crude.

Throughout the fall, while official and unofficial diplomatic efforts continued to try to pursuade Iraq to release the hostages and withdraw from Kuwait, ground, air and sea forces from many nations massed in the Persian Gulf. U.S. forces would eventually exceed 500,000 troops. Oil prices were up and stayed up, reaching $40/bbl on October 11 and then retreating to close at $33.82/bbl for WTI on October 19.

On November 29, 1990, the Security Council passed Resolution 678 authorizing member states to "use all necessary means" to remove Iraq from Kuwait and assure compliance with other U.N. resolutions. President Bush invited Iraq to meet to discuss the Persian Gulf Crisis between December 15 and January 15, 1991. WTI closed at $29.08/bbl on November 30th. Crude oil spot and futures prices trended slightly lower as preliminary talks got nowhere, Iraqi forces dug in, and coalition troops, equipment, and material built up.

On January 8, 1991, the President asked for a congressional resolution approving the use of all necessary means including force to end Iraqi occupation of Kuwait. WTI was $27.50/bbl. On January 12, following 2 days of prolonged debate, the House and Senate sent a resolution (H.J. Res. 77, P. 102-1) to the President authorizing the use of military force to implement U.N. Resolution 678 and expel Iraq from Kuwait. On January 16, as called for in the joint resolution, the President certified his decision to use military force after all diplomatic efforts to enforce Iraqi compliance had failed. Allied aircraft then began bombing Iraqi installations in Iraq and Kuwait in the beginning of an intense military campaign dubbed "Desert Storm." WTI crude prices rose to close at $32.25/bbl, only to fall to $21.48/bbl on January 17.

In the weeks that followed, the aerial bombardment continued unabated and oil prices hovered around $21/bbl.

In early February, Iraqi representatives began signaling a willingness to withdraw from Kuwait, but rejected compliance with all U.N. resolutions. Efforts to negotiate a diplomatic resolution again failed. On February 22, WTI spot prices closed at $17.43/bbl. On February 23, coalition forces began a ground invasion to liberate Kuwait, and in less than 100 hours forces led by Kuwaiti, Saudi, and other arab forces entered Kuwait City. Military operations were suspended on February 28, pending agreement on a permanent ceasefire among the parties. The oil fields of newly liberated Kuwait were left blazing by retreating Iraqi troops. Preliminary estimates were that it could take 1 to 2 years just to put out the fires.

Even as coalition forces stopped their assault against Iraq, ethnic and religious minorities within Iraq mounted armed resistance against the government of Saddam Hussein. This rebellion was met with ruthless retaliation by the remaining loyal armed forces. The counterattack created a flood of refugees. Even as U.S troops were being sent home from the Persian Gulf, other troops were deployed to Northern Iraq to create safe havens for Kurdish refugees. The situation in the region remains unstable. Oil prices, however, have remained low. By early July, average world crude oil prices were $16.72/bbl.[22]

The embargo of Iraqi and Kuwaiti crude and product exports removed 4.9 MMB/D from world markets, about 9 percent of free world production. This supply disruption came at a time when world oil stocks were higher than in recent years and oil production capacity worldwide exceeded demand by more than 5 MMB/D. As in previous disruptions, the price impacts were far larger than any physical shortage of crude or oil products. Even so, oil prices have not reached the levels set in 1981 of $40/bbl-which adjusted for inflation would equal a price of $55/bbl today. In fact, except for a brief tightening of petroleum feedstocks in Asian markets owing to the loss of Kuwaiti refining capacity, oil supplies remained plentiful. By the beginning of November surge production capacity had wiped out any crude shortfall, and by early January there was again surplus production capacity available—excluding any Iraqi or Kuwaiti capacity.

## OUTLOOK

It is too soon to know the full outcome of events surrounding the 1990 Iraqi invasion of Kuwait and the Persian Gulf war. The enhanced influence of futures markets on the volatility of oil prices was amply demonstrated. Yet, there were few, if any, actual shortages of crude oil or refined products. The combination of conservation, underutilized production capacity, private oil stocks, and government-held strategic reserves has so far been great enough to meet the world's oil needs. Yet the costs of the disruption went far beyond any loss of production. Higher oil prices added tens of billions of dollars to world and U.S. oil bills. Great hardships were imposed on many poor and populous developing countries, which are even more reliant on imported oil than the United States. The full costs of mounting the Desert Shield-Desert Storm operations have yet to be quantified, but are likely to total well into the tens of billions of dollars.

Although allied forces succeeded in ousting Iraqi invaders from Kuwait and restoring some sense of security to other nations in the Gulf, the destruction wrought on Kuwaiti and Iraqi oil fields will not be so quickly repaired.

What will happen with another oil supply crisis? How well is this Nation equipped to meet this challenge? Will our technological options prove as sure and swift as our the military response to Saddam Hussein's aggression? The following chapter examines our technical capability to replace lost oil imports in the event of a serious and prolonged oil supply disruption.

[22] U.S. Department of Energy, Energy Information Admininstration, *Weekly Petroleum Status Report: Data for Week Ending July 12, 1991, DOE/EIA-0208(91-30)* (Washington, DC: U.S. Government Printing Office, July 17, 1991), table 12.