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U.S. ENERGY VULNERABILITY IN THE 1990S: A REASSESSMENT

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U.S. ENERGY VULNERABILITY IN THE 1990s: A REASSESSMENT

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EXECUTIVE SUMMARY

The oil price collapse of 1986 and its effect on the world oil market were the original impetus for this study assessing U.S. energy vulnerability during the 1990s. While lower oil prices benefit the economies of oil importing nations, they also accelerated longer-term trends that increase our exposure to a supply interruption - increased oil demand and concentration of production among low-cost producers in the Persian Gulf. Energy vulnerability refers to the degree to which an energy supply and distribution system are unable to meet end-use demand as a result of an sudden, rare, unanticipated event of large magnitude. In assessing vulnerability, we include exposure and susceptibility to sudden shocks, not just the shocks themselves. In relative terms, vulnerability grows with increases in either the likelihood of damaging shocks or the damage that would result from a shock.

This report focuses on the oil supply system because it is most vulnerable to supply disruptions with major consequences for national security. Oil has been described as the world's most important primary commodity, supplying about 40% of U.S. total energy consumption, and an even larger share for our Allies (e.g., Japan, 56%; OECD, 42%). Oil is one of the most flexible and portable sources of energy; oil markets are global, interconnected, and integrated to a much greater extent than those of other fuels. Oil supply disruptions have occurred fairly frequently over the last 25 years and can have major economic impacts depending on the supply/demand balance, level of excess capacity, sharpness of the price response, the duration of the disruption, and the policy/political response of major oil consuming nations. Our economic vulnerability to oil supply interruptions is caused primarily by the great difficulty that the economy has in adjusting to large, unexpected increases in the price of oil. Sudden interruptions in oil supply can cause these price spikes because oil demand is very inelastic in the "short run" - large price increases are necessary to overcome small shortages. The economic losses come principally from macroeconomic adjustment problems (e.g., increased inflation, higher unemployment) as well as higher oil import bills. Low oil prices increases our dependence on low cost oil producers, principally the Persian Gulf countries. The increased share of world oil production from the Persian Gulf directly affects the level of damages that could potentially occur from a major interruption of supply from this volatile and unstable region. We also found that release of strategic reserves can substantially mitigate economic losses as government oil stockpiles can serve as temporary spare capacity during a supply disruption.

In assessing changes in oil vulnerability during the 1990s, we considered 1) the overall supply/demand balance, particularly decreases in spare production capacity and increased concentration of production in the Persian Gulf, 2) the likelihood, size, and duration of potential oil supply disruptions, and 3) the ability to minimize the effects of disruptions. The oil supply/demand balance is likely to tighten by the end of the 1990s under most conceivable price scenarios; current excess production capacity of 10 million barrels per day (MMBD) should be far less in this period. Oil demand is expected to increase relatively slowly (about 0.5-0.6% per year until 2000) in Western industrialized nations (i.e., OECD countries), even at low oil prices. Oil demand will be relatively flat in the OECD nations because of 1) improvements in the efficiency of oil-using capital stock, 2) shift of energy-intensive basic materials industry to LDCs, 3) substitution of other fuels for oil (e.g., nuclear- and coal-based electricity generation), 4) fierce inter-fuel competition that will limit switching to oil in industrial and power generation markets, and 5) high prices for final petroleum products as a result of government-imposed taxes, even at low oil prices, which will tend to depress demand.

In contrast, oil demand is expected to increase significantly in less developed countries (LDCs), even at relatively higher oil prices. LBL's International Energy Studies Group projects that LDC oil demand will reach 24 MMBD by the year 2000, increasing at about 3.8% per year (Table ES-1). The forces of urbanization and industrialization will continue to place upward pressure on commercial energy demand. The LBL forecast is significantly higher than other projections -- it is at least four million barrels per day more than Chevron is projecting for these same countries by 2000.

Table ES-1

LDC Oil Demand Forecast
(Million Barrels Per Day)

	1985	1990	2000
Asia	4.06	4.5	6.3
China	1.76	2.3	3.5
Africa	1.72	1.9	2.8
Latin America	4.43	5.4	8.1
Middle East	1.98	2.3	3.2
TOTAL	13.95	16.2	24.0

In assessing world oil demand, we conclude that particular attention should be focused on LDC's because their share of world oil demand is growing fairly rapidly and because the diversity of LDC energy markets and relative lack of reliable data is a major source of uncertainty in oil demand forecasts.

Barring any major new discoveries, crude oil supplies from non-OPEC producers will most likely decline by at least two or three million barrels per day during the next fifteen years because non-OPEC producers have limited reserves and higher production costs than OPEC producers. U.S. domestic oil production is projected to decline because of lower production from Alaskan and older domestic fields in the 48 contiguous States, and because of relatively low world oil prices that tend to discourage exploration and development activities. Thus, the fraction of the world's oil production that comes from OPEC countries and the Persian Gulf will almost certainly increase during the 1990s. Such a shift is almost inevitable given the increased requirements for imported oil and the fact that about 65% of the world's proved oil reserves are in the Persian Gulf and that over 90% of the world's surplus production capacity resides in OPEC nations.

Figure ES-1 shows high and low oil price forecasts of various oil companies, the Department of Energy (DOE), and the Gas Research Institute, along with our estimate of price ranges for low and high oil price scenarios (the shaded area). Forecasting future oil prices is particularly difficult as oil prices have stubbornly refused to behave as predicted during the last 15 years. The price trends are presented as relatively smooth paths; however, it is likely that actual price trends will be more erratic and cyclical than the smooth rates represented in the projections. The high oil price scenario assumes moderate and improving economic growth rates over the next 15 years (2-3%/year), some degree of OPEC cohesion and agreement on production and pricing levels, and that these price levels will not suppress demand or stimulate large-scale exploration in high-cost frontier areas. The low oil price scenario is more likely to occur if OPEC producers decide to maintain market share through higher production, even if it means lower prices, or if the demand for oil does not respond strongly to the current low price regime.

By the year 2000, oil prices are projected to be in the $28-34/barrel range under the high oil price scenario, and between $18-24/barrel in the low price case (expressed in 1986$). Relative to the high oil price scenario, U.S. oil demand could increase by 1-1.5 million barrels per day and production could decrease by 1-2 MMBD given a sustained period of low oil prices (Table ES-2). By the mid-1990s, even with higher oil prices, the United States will need to import about 50% of its oil; imported oil is likely to supply over 60% of our requirements in the event of lower oil prices. U.S. oil imports could range between 8 and 11 MMBD, depending on oil prices, a significant increase from the current level of 5 MMBD. Our Allies in the OECD countries are expected to be even more dependent on imported oil, with requirements of between 13 and 16 MMBD by the mid-1990s. OPEC exports as a fraction of non-Communist world oil demand are likely to exceed 50% by the mid-1990s, approaching levels obtained in the 1970s, compared to their current share of 30%. Saudi Arabia, Iran, and Iraq are likely to be the principal swing producers.

Table ES-2

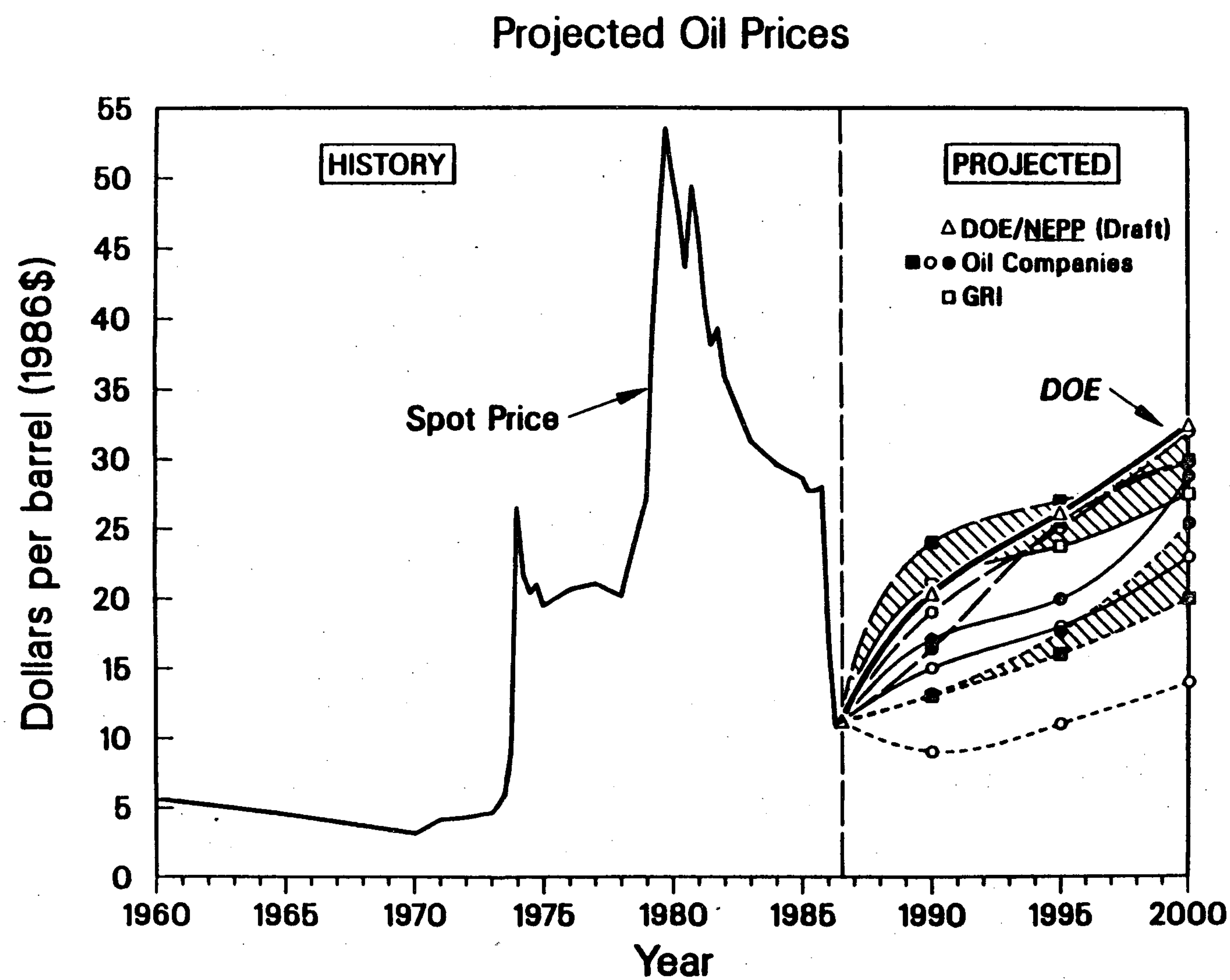
World Energy Outlook: High and Low Oil Price Scenario

	High Oil Price Scenario			Low Oil Price Scenario
	1990	1995	2000	1995
Oil Prices (1986 $/bbl)	20	26	33	15-20
U.S. Oil Demand (MMBD)	17.0	17.0	17.1	18-18.5
World Oil Demand (MMBD)	50.2	52.1	54.6	53-54
U.S. Domestic Oil Production (MMBD)	9.4	8.0	7.2	6-7
U.S. Energy Demand (Quads)	83	89	94	88-91
% U.S. Imports	41	49	55	62-67
% World Oil Supplied by OPEC	46	52	56	62

We conclude that our exposure to an oil supply disruption will increase substantially in the 1990s for the United States and its Allies because the world oil supply/demand balance will be tighter and because, compared to today, much more of the world's oil production will again be concentrated in the Persian Gulf, a small and politically unstable region. In addition, it is worth noting that there is a high likelihood that the current excess capacity that exists in much of the U.S. gas and electric industry will be substantially reduced by the mid-1990s, which will further limit response flexibility and options, and thus increases our exposure relative to the current situation. A recent study by Rowen and Weyant estimated that a year-long supply interruption of 50% of oil production from the Persian Gulf during the mid-1990s would cause economic losses of between four and six percent of U.S. GNP under high and low oil price scenarios, respectively (assuming no release of strategic reserves). Use of government-held strategic petroleum reserves significantly reduces economic losses - by almost a factor of two (e.g., from six to about three percent of U.S. GNP in the low oil price scenario) although the dollar magnitude of losses are still enormous (Figure ES-2). It is important to note that the scenarios considered by Rowen and Weyant are larger than actual disruptions that have occurred, although they are internally consistent and plausible for use in a vulnerability assessment.

The report is organized into the following chapters. In Chapter 1, we define energy vulnerability, discuss the context of this study, and describe the limitations on its scope. The next two chapters trace the international and U.S. response to the oil price shocks of the 1970s. In Chapter 2, we show how the underlying forces of weak demand for oil, increases in non-OPEC production, and OPEC's loss of market share fundamentally altered the basic oil supply/demand balance and the international politics of oil, which set the stage for the sharp fall in oil prices that occurred in early 1986. Chapter 3 discusses key trends that have influenced the U.S. energy system during the last decade, in the context of assessing vulnerability: 1) greater reliance on market forces and deregulation of some energy markets, 2) increased development of domestic energy sources, 3) conservation, 4) development of the Strategic Petroleum Reserve, strengthened IEA agreements, 5) inter-fuel substitution and increased reliance upon electricity, and 6) increased fuel-switching capability in industrial and power generation markets. In general, we conclude that the economic and political responses to the energy price shocks of the 1970s have produced a more flexible and resilient energy system in the United States.

Chapter 4 discusses the energy supply and demand outlook during the 1990s and presents two possible world energy outlooks that are linked to higher and lower oil prices. Chapter 5 focuses on oil vulnerability and discusses key threats to the international oil supply system, assesses changes in U.S. oil vulnerability during the next decade, analyzes the effects of strategic inventories in mitigating a possible supply disruption, and presents quantitative indicators of U.S. vulnerability under several different conditions.



Source: DOE/NEPP (Draft); GRI; Ashland; Chevron; Conoco

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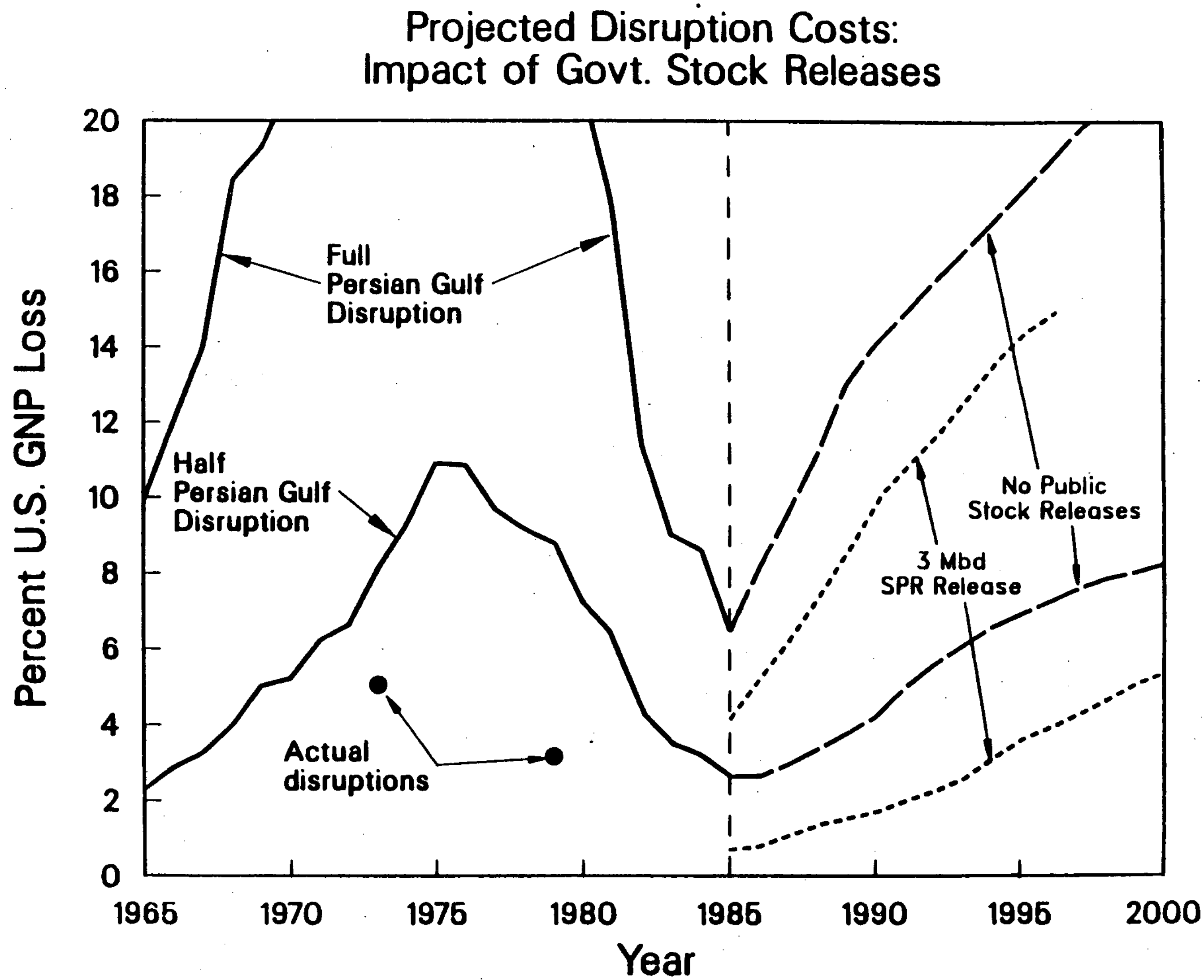
Figure ES-1. Current forecasts of future oil prices by various oil companies, industry groups, and government agencies. Shaded area shows range of higher and lower oil price paths.



Source: Rowen & Weyant, "The Oil Price Collapse and Growing American Vulnerability"

Figure ES-2. Effect of releasing government-held strategic oil stocks on projected costs of an oil supply disruption.

Chapter 1

INTRODUCTION

Background

The vulnerability of the U.S. energy system is a major national security concern. The economy of the United States--the nation's ability to produce goods and services and the value of its capital equipment and infrastructure--depends upon a steady supply of energy. Experience during the 1970s showed that even relatively small disruptions in U.S. oil supplies can cause huge economic losses. In 1973, a four-month disruption in oil supply affecting about 20% of the oil produced by Arab OPEC members, reduced the U.S. GNP by 5% for one year and, in 1979-80, a similarly small disruption caused by the Iranian revolution and the Iran-Iraq war reduced the GNP by 3%.[1]

For many years, concern about the security of the U.S. energy supply has influenced government policies and led to the creation of government programs. Throughout the 1960s, for example, the U.S. operated under an oil import quota that held the domestic price of oil well above the world price. This policy was intended to reduce U.S. dependence on insecure foreign oil supplies. Currently, many government policies encourage the discovery and development of domestic energy sources. In addition, two major government programs are designed to improve the security of U.S. energy supply: 1) the development of the Strategic Petroleum Reserve, and 2) U.S. involvement in the International Energy Agency (IEA), a cooperative arrangement with other nations that import oil.

As part of a program review, the Department of Energy's Office of Energy Emergencies is reexamining U.S. energy vulnerability in the 1990s. This is a propitious time for such a review, since a recent dramatic collapse of world oil prices has allowed us to observe the start of the chain of events that that collapse has set in motion. The 1990s is the first period during which changes in policies and programs can have a major effect on U.S. energy vulnerability, and as will be discussed below, it also appears to be a time of greatly increased U.S. energy vulnerability.

The Scope of the Energy Vulnerability Problem

Glassey and Craig have defined energy vulnerability as follows:

> ''Vulnerability refers to the degree to which an energy supply and distribution system is unable to meet end-use demand as a result of an unanticipated event which disables components of the system. The kinds of events referred to are sudden shocks, rare, and of large magnitude.''[2]

This definition is a good starting point but requires some modification. First, vulnerability suggests the *exposure and susceptibility to* sudden shocks rather than the shocks themselves. Vulnerability is like the presence of a volatile mixture in an area where sparks may occur, rather than the sparks themselves. Thus, vulnerability may increase gradually even though the shocks are sudden. In particular, vulnerability includes susceptibility to the effects of sudden recognition of the importance of a gradually developing economic, environmental, or safety problem. Vulnerability grows with increases in either the likelihood of damaging shocks or the damage that would result from a shock.

Vulnerability is not synonymous with use of imported energy. Imports may be more or less subject to sudden shocks, and the nation may be more or less able to withstand them. Furthermore, domestic energy supplies may also be vulnerable.

This study focuses on the elements of the U.S. energy system that are vulnerable and linked to U.S. security. However, the security issue involved is not primarily that of energy for military operations. The energy needs for purely military purposes tend to be low. (Even during the height of the Vietnam war, the military accounted for no more than 10% of U.S. energy consumption.) Direct and indirect economic effects of energy vulnerability on U.S. security are the dominant concern in this report, because, in the long run, U.S. security depends principally upon our economic strength. Overall, it is useful to classify as a security concern of the nation any matter, military, diplomatic, or economic, over which the nation might be prepared to use military force. Civilian programs designed to reduce energy vulnerability are alternatives to military actions.

There are a number of limitations on the scope of our study. For example, we did not consider the vulnerability of the U.S. energy system to nuclear war, not because it does not exist, but because it is dwarfed by the larger concerns of such a war. Similarly, we omit the energy vulnerability aspects of any other major changes which are speculative and for which energy is not an important focus. We also do not focus on events that are too small or too local to be of national security concern. Thus, the effects of earthquakes, tornados, and isolated blackouts are not discussed in detail. Finally, we do not consider vulnerability to gradual changes of an *inherently* economic nature. Thus, for example, we are not concerned about the possibility of a gradual development of a refining capacity shortage, except as it contributes to our susceptibility to sudden shocks. We are, however, deeply concerned about political and military events with economic consequences, such as the ones that interrupted Persian Gulf oil supplies in the 1970s.

Approach and Organization of the Report

In this study, we assess and discuss the most critical international threats to U.S. energy security during the 1990s, in the context of two different oil price forecasts. We also summarize the degree to which a consensus exists on key issues: the supply/demand outlook, the response capabilities of various U.S. energy systems, and agreement on most serious threats. In preparing this report, we reviewed previous studies of the vulnerability of U.S. energy systems and the impacts of past supply disruptions, recent analysis of key trends in world oil and energy markets, and forecasts of future supply and demand. The report focuses on the oil supply system, because it is most vulnerable to supply disruptions with major consequences for national security.

In Chapter 2, we review key changes that occurred in the world oil market following the sharp price increases of the 1970s and that helped create the conditions for the recent oil price collapse: weak demand for oil, increased market share and influence of non-OPEC producers, and declining OPEC production. We briefly describe the history of the U.S. energy system in order to provide a context for the current situation (Chapter 3). In general, we conclude that the economic and political responses to the energy price shocks of the 1970s have produced a more flexible and resilient energy system in the United States. In Chapter 4, we discuss the energy supply and demand outlook during the next decade and present two plausible scenarios, one in which oil prices will be higher, and one in which they will be lower. Chapter 5 focuses on oil vulnerability. We discuss key threats to the international oil supply system, assess changes in U.S. oil vulnerability during the next decade, analyze the effects of strategic inventories in mitigating a possible supply disruption, and present quantitative indicators of U.S. vulnerability under several different conditions.

Notes to Chapter 1

1. H.S. Rowen and J. P. Weyant, " The Oil Price Collapse and Growing American Vulnerability", (draft), 1986, p. 4.
2. W. Clark, *Dispersed, Decentralized and Renewable Energy Sources: Alternatives to National Vulnerability and War*, Federal Energy Management Agency, December 1980, p. 1.

Chapter 2

MAJOR TRENDS IN THE WORLD OIL MARKET

In this chapter, we highlight key developments in the world oil market, focusing on the changing roles of the major oil companies and producer nations. We analyze forces that were set in motion as a result of the sharp oil price increases of the 1970s: the changing structure of world oil demand, the growth in non-OPEC oil supplies, and effects of these two changes on OPEC oil production and revenues. Finally, we show how the underlying forces of weak demand for oil, increases in non-OPEC production, and OPEC's loss of market share fundamentally altered the basic supply/demand balance and the international politics of oil, which set the stage for the sharp fall in oil prices in early 1986.

Background

During the second half of the nineteenth century, the oil industry was comprised of many small producers, refiners, and marketers. However, as early as 1880, a few large multinational companies began to dominate the industry. These companies were integrated vertically and sought control over all aspects of the production process -- linking upstream with downstream, and production with refineries and end-use markets. Initially the companies tried to obtain ownership of crude oil at its source. The first Middle East oil concession included nearly 87% of the territory of contemporary Iran and was given to William D'Arcy (later taken over by British Petroleum) by the Shah of Persia in 1901 for a period of 60 years.[1]

U.S. companies could not gain access to Middle East oil until the 1920s, through participation of Mobil and Exxon in the Turkish Petroleum Company, and only then because of substantial political pressure by the U.S. government. By the late 1920s, the major oil companies were concerned about a potential oil glut and price wars. In 1928, the major companies negotiated the Red Line and the Achanerry agreements, which gave them market control and enabled them to achieve relative price stability. In the Achanerry agreement, Royal Dutch Shell, Anglo-Persian, and Standard Oil of New Jersey sought to preserve markets and limit competition by 1) accepting each participant's market share as fixed, 2) adding new facilities only as needed, 3) preventing surplus production from one area from upsetting price structure in another area, and 4) developing a uniform pricing structure for delivered oil regardless of its actual origin.[2] In the Red Line agreement, the companies participating in the Turkish Petroleum Company agreed not to pursue independent development of oil resources in an area including Saudi Arabia, Iraq, Syria, Jordan, Turkey, and Israel, and, in essence, established the first joint venture. Additional agreements were negotiated during the 1930s, in response to price cuts that resulted from large new discoveries (e.g., in East Texas) and reduced demand from the Depression. We can see that OPEC's post-1970 price fixing and production quotas are not without historical precedent.

In summary, from the 1920s to mid-1960s, international oil markets were dominated by a relatively small number of major oil producing companies. Oil prices were relatively stable, low, and, in real terms, declining (Fig. 2-1). Stability during this period came in part from: 1) strong barriers to market entry, 2) production controls in the U.S., the one country where market entry was relatively easy, 3) vertical integration and planning, 4) consortium agreements and joint ventures that guided expanded production among the major producers and 5) uniform pricing.[3] In most cases, the major oil companies internalized the impacts of various economic and political crises, such as the Depression and World War II, during this period. The major oil companies' control was epitomized by their ability to circumvent producer nations' attempts to gain greater control of their own oil resources. For example, in 1951, Iran, following in the footsteps of Venezuela, attempted to raise its profit-sharing royalties from Anglo-Iranian from 12.5 to 50%. The Iranian National Assembly refused a counter-offer from Anglo-Iranian and, in May 1951, under the leadership of Mossadegh, attempted to nationalize Anglo-Iranian, establishing a state-owned company, the National Iranian Oil Company (NIOC). The other oil companies, in response, successfully boycotted Iranian oil; Iranian oil exports fell to less than $1 million per year between 1951 and 1953, compared to over $400 million in 1950. Prior to the boycott, Iranian oil accounted for almost 20% of world exports, but the oil companies were able to offset the loss of Iranian oil by increasing production in the other Persian Gulf nations. Finally, in 1953, Mossadegh was overthrown in a CIA-supported coup, and the oil companies regained effective control over Iranian production.[4]

The first crack in this system came in the late 1950s with the appearance of independent oil companies in international markets. The independents, who offered to oil-producing nations more generous terms than the major companies, got concessions in newly independent countries like Libya, Algeria, and Nigeria. During the early 1960s, independent producers developed aggressive marketing strategies, particularly price-cutting, as the majors' share of world oil production began to decline.

In 1960, at about the same time as the independents' move into international markets, OPEC was formed by five major producer nations, initially as a reaction to the major oil companies *unilateral* reductions in posted oil prices. During the 1960s, OPEC achieved some limited gains, including a greater share of oil company profits. Then, in 1968, OPEC announced its intention to seek ownership of production and control over production and prices. The significance of the OPEC policy declarations became apparent only in June 1970 when Libya, led by Colonel Qadaffi, successfully reduced the production quota of Occidental Petroleum Company by 45%, and got Occidental to raise the posted price of low-sulfur crude and agree to a retroactive tax increase.[5] The Libyans won this agreement by taking advantage of rivalry between the major and independent oil companies, Occidental's dependence on Libyan oil, a tight European oil market, and the U.S. military's relative unavailability to respond to the situation because of its involvement in Vietnam. Other countries were quick to use the Libyan strategy and assert their authority, which led to agreements at Teheran and Tripoli in early 1971. As a result of these contracts, for the first time, posted prices for oil were set by oil companies and host governments together. Two years later, in October 1973, the OPEC countries unilaterally decreed an increase in posted prices, while a group within OPEC, the Organization of Arab Petroleum Exporting Countries (OAPEC) announced production cutbacks. The OPEC governments also moved toward complete ownership of producing operations as the major oil companies accepted the reality that *defacto* control of oil had passed to the host governments. The oil companies then negotiated compensated transfers of title to the oil, maintaining various degrees of involvement in production and marketing. Within a decade, a profound transformation occurred in the ownership of oil reserves. In 1970, seven major companies owned 61% of world reserves and moved about 90% of the internationally-traded oil. By 1981, the seven companies owned 31% of world reserves.[6]

From 1965 to 1973, world oil demand grew at six to seven percent per year, because of economic growth, declining real oil prices, and the resulting switching from other fuels. By 1965, the Middle East had displaced the United States as the world's largest crude oil producing area. During this period, crude oil production from OPEC nations grew from 14 million barrels per day (MMBD) to 31 MMBD, an increase of 120%. The growing dependence on OPEC production set the stage for the two oil price shocks, in 1973-74 and 1979-81, during which the official price of Mideast Light Crude Oil jumped from $3.00/barrel to almost $33/barrel (Fig. 2-1).

Impact on World Oil Demand

World oil demand decreased after the 1973-74 embargo but recovered within two years (Fig. 2-2). This rather mild response to very large price increases reflects the low short- and medium-term demand elasticity of oil; large changes in price induce relatively small changes in consumption. Non-communist world oil consumption peaked in 1979 at 51.2 MMBD, and has declined by 11% through 1984.

A look at the components of world demand indicates that growth in oil demand has shifted from the industrialized nations to the less-developed nations and centrally planned economies. Between 1970 and 1985, the share of world petroleum demanded by the Organization for Economic Cooperation and Development (OECD) fell from 71% to 57%, while demand from less-developed countries (LDCs) increased from 14% to 23% (Fig. 2-3). Oil demand in OECD countries has actually dropped by around six MMBD from 1973 levels (declining at an annual rate of 1.3%) as a result of decreasing economic growth rates, conservation, and fuel substitution. Exchange rate movements between 1980 and 1984, specifically the appreciation of the dollar relative to major European currencies, also tended to dampen demand in some OECD nations.[7] For example, between the fourth quarter of 1980 and the first quarter of 1984, real oil prices actually increased in France, Germany, and the United Kingdom (by 23%, 14%, and 17% respectively), in sharp contrast to the 25% drop in U.S. real prices (Table 2-1).[8]

Table 2-1

Percentage Changes In Imported Oil Prices (Real $)[a]

	France	Germany	U.K.	Japan	USA
Oil Shock and Recession: 1973:1-1976:4	233.5	203.8	275.5	228.1	230.2
Dollar Depreciation: 1976:4-1978:4	-20.3	-20.5	-21.2	-34.5	-4.0
Oil Shock II 1978:4-1980:4	199.3	131.2	47.4	153.1	106.5
The Dollar's Rise: 1980:4-1984:1	22.5	14.4	16.6	-.51	-24.9
(1980:4-82:4)	36.0	26.8	25.4	26.2	-6.4
(1982:4-84:1)	-10.0	-9.8	-7.0	-24.8	-18.7

[a] 1 Real oil prices are measured as the marker price of Saudi Arabian oil, in dollars, divided by a domestic price index for each country, also expressed in dollars. Exchange rates and oil prices from the International Monetary Fund, *International Financial Statistics*. Price indexes are gross domestic product deflators, from OECD *Main Economic Indicators*, except for France, where the consumer price index (from the IMF *IFS*) is used.

Source: Cambridge Energy Research Associates, *The Third Oil Shock: Exchange Rates and Prices*, July 1984.

Growth in non-OPEC Oil Supplies

The oil price increases of the 1970s also set in motion an intensified search for oil supplies in nations outside of OPEC. Between 1974 and 1984, approximately 7.5 MMBD of new production capacity were added outside OPEC in the non-Communist world. Major discoveries in the Alaskan North Slope, the North Sea, and Mexico began to have an impact during the late 1970s and early 1980s. In addition, other countries were able to increase their oil production, so they could rely less on oil imports (e.g., Brazil and India increased production by 850 thousand barrels per day between 1977 and 1985). The net effect of these oil supply additions was that non-OPEC producers gained market share and influence. Currently, the world oil market consists, in broad terms, of two streams of producers: OPEC and non-OPEC. The non-OPEC producers are principally medium- and high-cost producers who supply at or near capacity. Low-cost OPEC producers, in contrast, are operating well below sustainable capacity and have become the swing or marginal producers.[9] Morris Adelman sees this combination as analogous to "water running uphill" and notes that:

1) prior to 1973, development of reserves followed a pattern that was more typical of a competitive market: low-cost reserves were being developed at an accelerating rate, while development of high-cost reserves was slowing down, and

2) since 1973, higher cost reserves have been developed by "price takers" who have responded to high oil prices, while the Saudis, the chief price makers, have restricted investment and output to maintain a high price.[10]

Impact on OPEC Production and Revenues

Changes in the world oil market brought about by reduced demand, particularly in the OECD nations, and increased non-OPEC oil production have occurred at the expense of the OPEC producers. The demand for oil from OPEC producers has dropped dramatically -- from 31 MMBD in 1979 to 17.4 MMBD in 1984 (Fig. 2-4). OPEC production has mostly decreased in Saudi Arabia, Iran, and the other Arab OPEC nations. These producers have been willing to adjust production to promote their economic and political goals and have not behaved as competitive producers in classical economic terms. They have become the residual or swing suppliers in a world oil market that has an estimated 8-10 million barrels per day of unused capacity, most of which belongs to OPEC (Table 2-2).

Table 2-2

Current OPEC Production Capacity

(Million Barrels Per Day)	Installed	Maximum Sustainable[a]	Available[b]
Saudi Arabia	12.84	10.30	8.10
Iran[c]	7.00	5.50	3.20
Kuwait	3.24	2.30	1.55
Iraq	4.00	3.50	1.75
United Arab Emirates	2.55	2.42	1.55
Qatar	0.65	0.60	0.60
Libya	2.50	2.10	1.75
Algeria	1.20	0.90	0.90
Nigeria	2.50	2.20	1.90
Gabon	0.25	0.25	0.25
Ecuador	0.30	0.29	0.29
Venezuela	2.60	2.50	2.20
Indonesia	1.80	1.65	1.65
Total OPEC	41.43	34.50	25.69

[a]Maximum sustainable capacity represents the production level that can be maintained for several months.

[b]Available capacity reflects production ceilings of various countries and limitations on Iraq because of the Iran-Iraq war.

[c]In both Iran and Iraq, maximum sustainable capacity refers to capacity before the war and does not take into account effects of the war.

Source: Arthur Anderson & Co. and Cambridge Energy Research Associates, *World Oil Trends: A Statistical Profile*, 1986.

OPEC revenues peaked at $275 billion in 1980 and declined to $134 billion in 1985, which is comparable to revenues in the mid-1970s (Fig. 2-5). OPEC revenues are projected at between $80 and $90 billion for 1986. Since oil revenues account for 90% of OPEC countries' total export income, Thus, falling revenues have created severe economic difficulties for many of these nations. Those oil-exporting nations with large populations or huge foreign debts, Mexico, Nigeria, and Indonesia, have been particularly hard hit. In addition, Iraq and Iran require large revenues to sustain their war against each other. OPEC hoped to increase falling revenues by stimulating demand through lower prices (e.g., in 1983 OPEC dropped the price of oil from $34 to $29 million barrels per day). However, these price reductions were effectively negated by the rapidly appreciating dollar, which meant that the real price of *imported* oil was actually increasing in much of Western Europe from 1981 through 1983.[11]

During the 1980s, the oil supply glut has led to continuing downward market pressure on oil prices. OPEC has had increasing difficulty in maintaining official prices and production quotas. Periodically, OPEC has reduced production and cut prices in response to mounting pressures. For example, in March 1983, OPEC adopted a crude oil production quota of 17.5 MMBD; only 18 months later, it was forced to reduce it to 16 MMBD. However, the revenue requirements of individual OPEC nations created strong temptations to "cheat", and several countries produced in excess of their individual quotas or offered price discounts in order to increase market share. By mid-1985, the glut in oil supplies had forced the principal residual producer, Saudi Arabia, to cut its production to less than three million barrels per day (compared to peak levels around 9.9 MMBD in 1980), well below its implied OPEC production quota. In August, Saudi production declined further to 2 MMBD. At that point, the Saudis decided to move aggressively to regain their lost market share. With their low production costs and large unused production capacity, they could, in principle, improve net revenues by increasing production and letting world oil prices fall.[12] The Saudis increased their production to around 4.5 million barrels per day during the first half of 1986, and guaranteed a market for much of this oil by agreeing to sell specified quantities of oil to several large oil companies using netback pricing arrangements.[13] In essence, the Saudis decided that they were no longer willing to prop up the world price of oil, which required them to cut back their production steadily. Along with some other Persian Gulf producers, the Saudis had reached the conclusion that falling prices would slow down conservation and the substitution movement away from oil, and stimulate renewed oil demand in the future.[14] In December 1985, OPEC formally announced that it would pursue a strategy in which it sought to achieve a certain share of the market (initially unspecified but estimated at between 17 and 20 MMBD). Following this meeting, increasing volumes of OPEC crude oil entered the world oil market accompanied by expectations of further increases, and prices began to fall sharply, from $26-28/barrel to less than $15/barrel in early 1986.

Notes to Chapter 2

1. Background material drawn from Exxon Background Series, *Middle East Oil and Gas*, December 1984, and W. G. Prast and H. L. Lax, *Oil-Futures Markets*, Lexington Books, 1983, pp. 30-36.
2. Prast and Lax, p. 36.
3. Yergin, Daniel and B. Kates-Garnick (ed.), ''Reshaping of the Oil Industry: Just Another Commodity,'' Cambridge Energy Forum, p. 28.
4. Exxon Background Series, p. 6; Prast and Lax, p. 42.
5. Exxon Background Series, p. 25; Prast and Lax, p. 54.
6. See Yergin and Kates-Garnick, *Reshaping of the Oil Industry*, p. 8, and Arthur Anderson & Company and Cambridge Energy Research Associates, *World Oil Trends: A Statistical Profile*, 1985 and 1986.
7. For much of the world, oil prices are determined by the U.S. dollar price of internationally traded oil as well as by the exchange value of the buyer's currency in dollars.
8. Cambridge Energy Research Associates (CERA), *The Third Oil Shock: Exchange Rates and Prices*, p. 4.
9. See Yergin and Kates-Garnick, *Reshaping of the Oil Industry.*
10. M. Adelman, ''An Unstable World Oil Market'', *The Energy Journal, 6:1*, January 1985.
11. CERA, *The Third Oil Shock: Exchange Rates and Prices*, p. 6.
12. Energy Information Administration, *The Impact of Lower World Oil Prices and Alternative Energy Tax Proposals on the U.S. Economy*, April 1986.
13. Arthur Anderson & Company and Cambridge Energy Research Associates, *World Oil Trends: A Statistical Profile*, 1986, p. 5. In netback pricing, the crude oil price is determined after the fact based on the buyer's final product mix, the market price value of these refined products at a specified date, with a profit margin included.
14. D. Yergin, Cambridge Energy Research Associates, ''Testimony presented to the Senate Finance Committee, Energy and Agricultural Taxation Sub-committee'', Feb. 28, 1986.

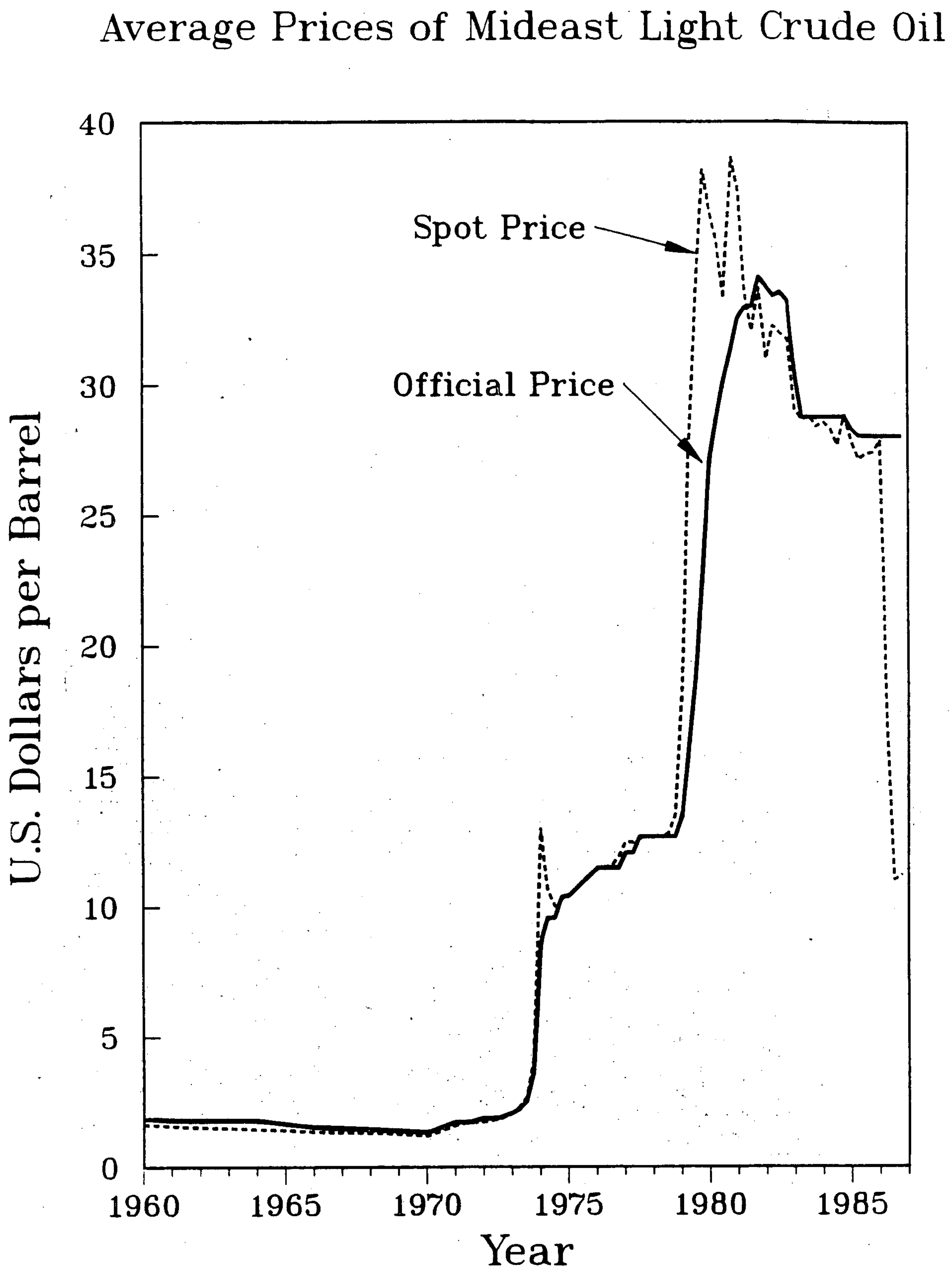


Figure 2-1. Official and spot prices of Mideast Light crude oil.

Source: Arthur Anderson & Co. and Cambridge Energy Research Associates, *World Oil Trends: A Statistical Profile*, 1986.

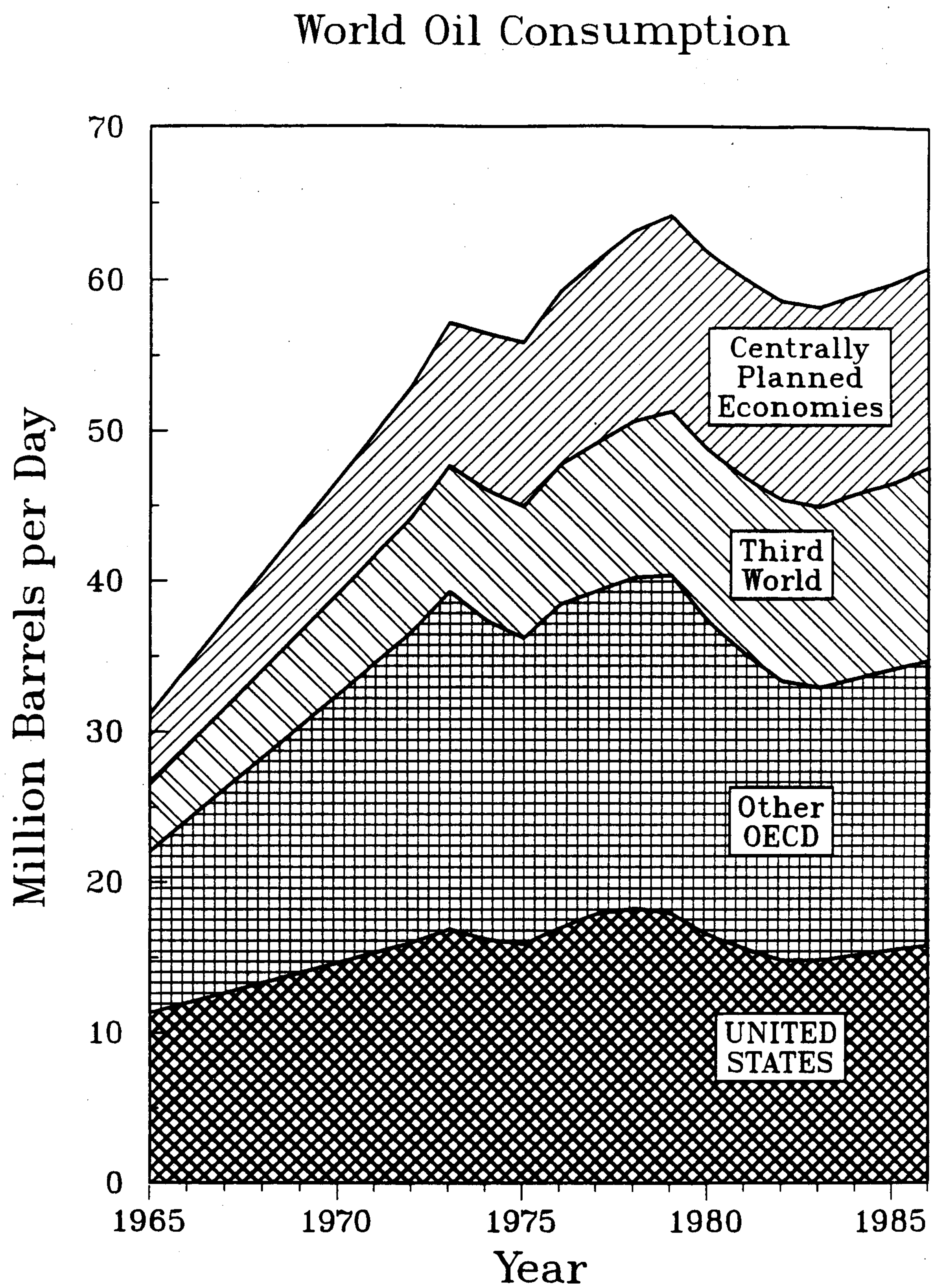


Figure 2-2. Trends in world oil consumption.

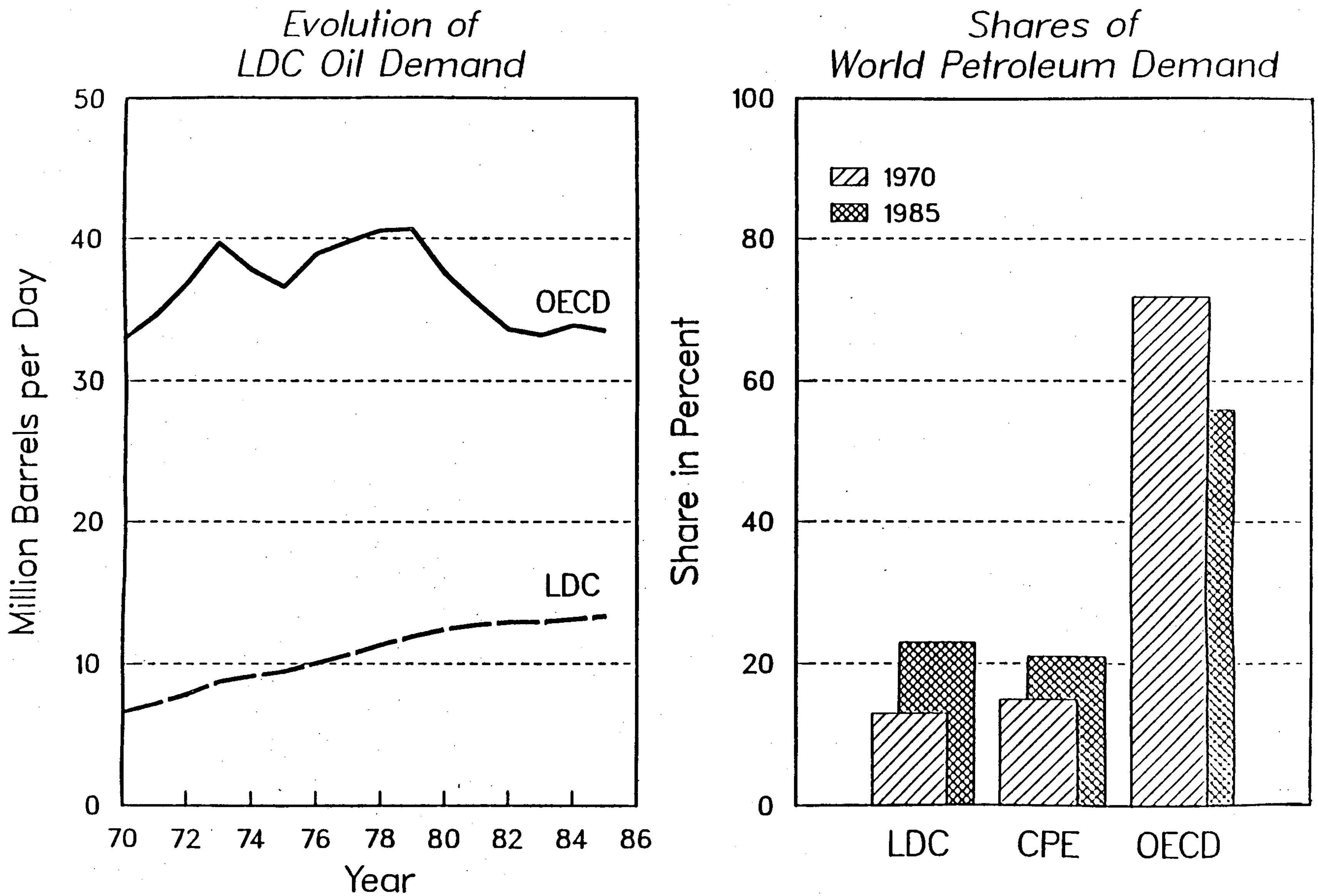


Figure 2-3. Evolution of world oil demand: trends in less developed countries (LDC), centrally-planned economies (CPE), and countries in the Organization of Economic Developed (OECD). Note that China is included among the LDCs.

Source: Lawrence Berkeley Laboratory, International Energy Studies 1986.

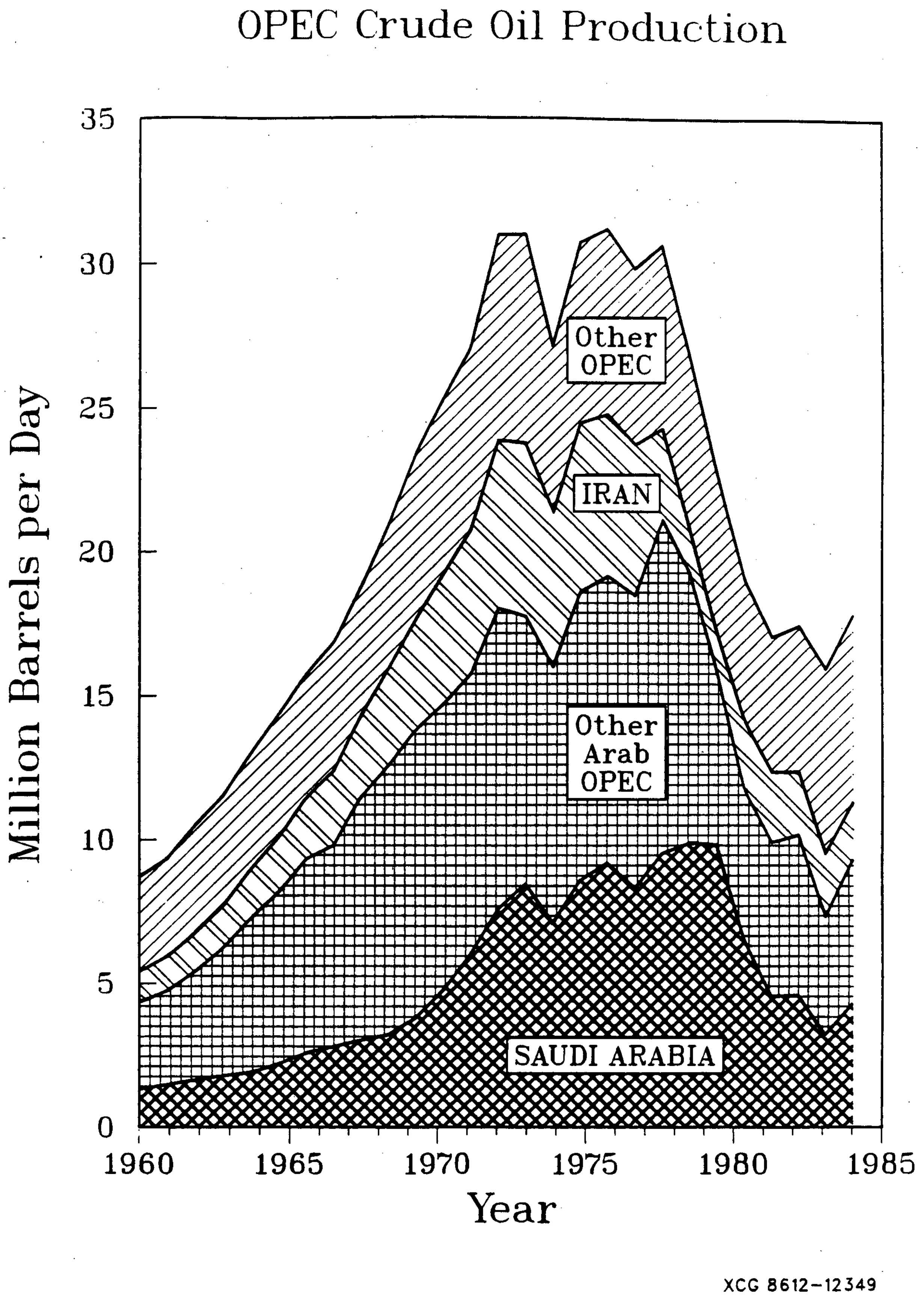


Figure 2-4. OPEC crude oil production.

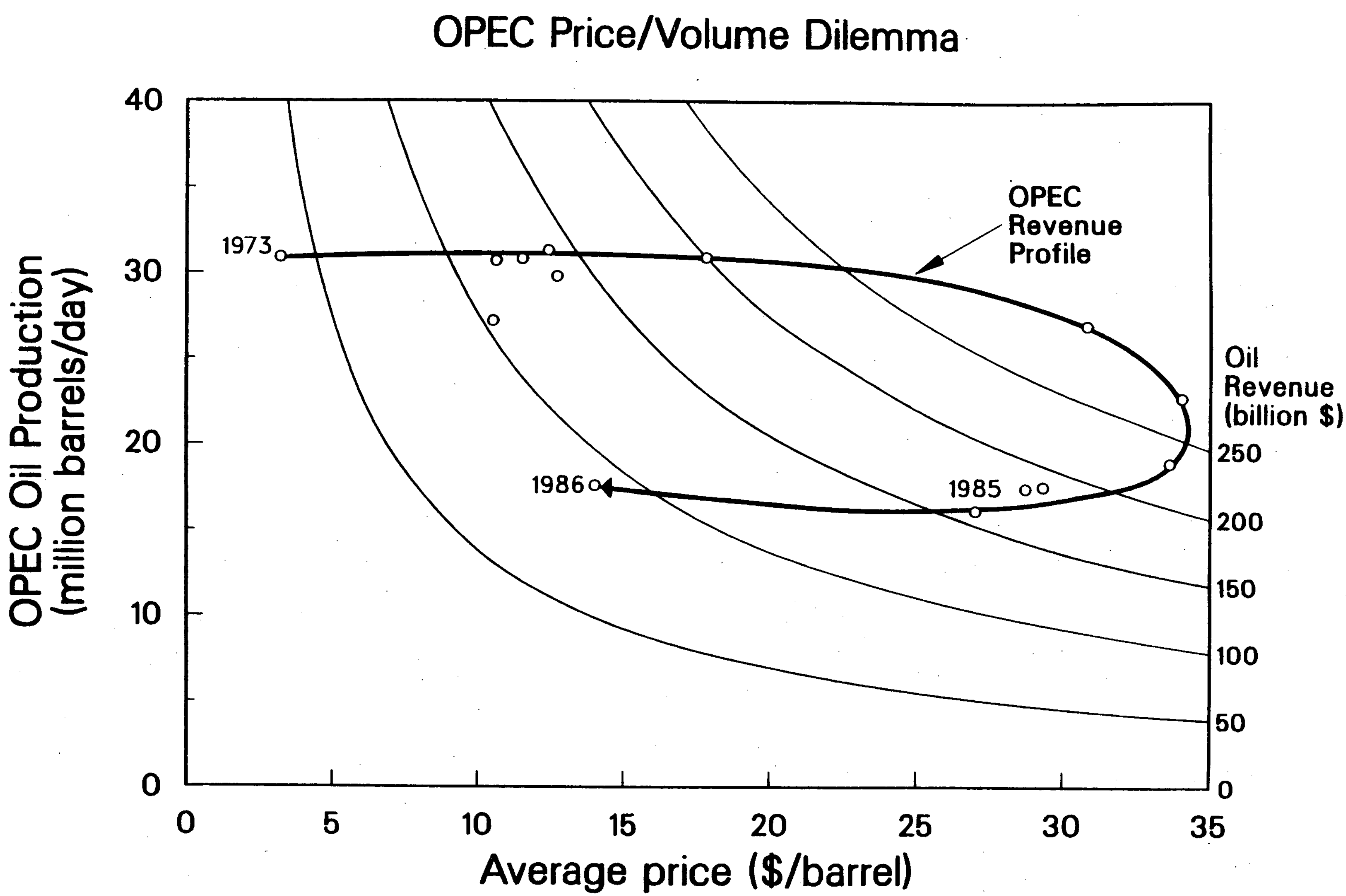


Figure 2-5. Historical trends in OPEC revenues: Impact of price and volume of exports.
Source: Shell Briefing Service, *The world oil scene and OPEC*, Number 2, 1986.

Chapter 3

EVOLUTION OF THE U.S. ENERGY SYSTEM: KEY TRENDS

In this chapter, we identify the major economic and political responses to the 1970s energy price shocks, focusing on those that significantly influence the current U.S. energy supply/demand picture. We also describe changes in the U.S. energy resource mix over time, analyze energy consumption patterns by sector, and examine trends in energy prices, all of which provide historical context for our assessment of U.S. energy vulnerability in the 1990s.

U.S. Energy Consumption: Historical patterns

The United States has large supplies of indigenous energy resources and has been able to rely on domestic energy sources to a far greater extent than other industrialized nations have. Fuel wood was the first major source of energy in the United States. At the turn of the 20th century, it was replaced by coal, which was increasingly used as industry and use of steam locomotives grew. U.S. coal production peaked at over 570 million tons in 1926, declined sharply during the Depression, and peaked again in the aftermath of World War II. U.S. oil drilling began around 1860. Oil was first used for lighting, heating, and lubrication. The invention of the internal combustion engine and subsequent rapid growth in number of vehicles powered with that engine dramatically increased oil consumption. The early history of the petroleum industry was a search for oil that involved accidental and sometimes annoying gas discoveries. Initially, natural gas was recovered with oil, but had little perceived value and was often flared. The advent of long-distance seamless welded pipe and industrial growth in the Southwest opened up significant markets for natural gas after World War II. By 1970, natural gas and oil (including imports) accounted for almost 77% of total primary energy consumption (Fig. 3-1).[1] U.S. oil and gas imports almost doubled between 1970 and 1980, from 7.7 to 14.5 quads. By 1985, the U.S. had reduced its reliance upon oil and gas somewhat, as their share of total primary energy use dropped to 66%.

Historically, the industrial sector has used the most energy (Fig. 3-2). However, since 1960, the industrial sector's share of total *primary* energy consumption has declined by eight percent, principally because of output declines in energy-intensive industries and because residential and commercial buildings' electricity use is growing faster than industry's.[2] In 1984, the industrial sector used roughly 28 quads of energy, residential and commercial buildings used around 26 quads, and the transportation sector consumed almost 20 quads.[3] Increased use of electricity and growth of a service-based economy explain much of the growth in commercial sector energy consumption. The resource mix is quite varied among the sectors of the economy. Of particular importance for this study is the transportation sector's overwhelming reliance on oil (Fig. 3-3).

Trends in U.S. Energy Prices

Energy has been widely available and inexpensive throughout most of U.S. history. From 1960 to the early 1970s, fuel and electricity prices were relatively constant or actually declined in real terms in all sectors (Fig. 3-4). Delivered energy prices increased rapidly, however, in the period following the oil price shocks of the 1970s, leveling off in the 1980s. The dramatic price increases contributed strongly to significant declines in primary energy demand growth rates in each sector.

The relative price of electricity during the last several decades has steadily declined (Fig. 3-5). For example, in the residential sector the ratio of the price of electricity to the price of gas decreased from 6.2 in 1970 to 3.7 in 1984 [Meyers, 1985]. The decreasing price ratio has contributed to growing reliance on electricity and has tended to increase inter-fuel competition in specific energy markets (e.g., residential space heating).

Finally, it is important to keep in mind the significant differences that exist in U.S. fuel and electricity prices between regions and among various sectors of the economy. For example, in 1982, residential electricity prices ranged from a low of $0.032/kWh in the Pacific Northwest to over $0.10/kWh in New York and New Jersey, while average gas prices for industrial users were almost 30% less than for residential customers. Inter-fuel competition in energy markets is particularly intense in regions with low electricity prices.

Major factors affecting the U.S. energy system during the early 1980s

The energy price shocks of the 1970s spurred a broad range of economic and political/institutional responses that have significantly affected the U.S. energy system during the 1980s (Table 3-1). In this section, we describe these major trends and quantify their impact on energy consumption patterns. We also include a brief discussion of major political initiatives that were specifically designed to improve energy security. In addition, we discuss structural changes in the U.S. economy, focusing on those that affect energy markets.

Table 3-1

Major factors influencing U.S. energy system

Macro-economic Trends

- Slow U.S. economic growth in the 1970s
- Changed structure and composition of U.S. economy

Economic

- Increased development of domestic energy sources
- Conservation
- Inter-fuel substitution: Increased reliance upon electricity
- Increased fuel-switching capability in industrial and power generation markets

Political/Institutional

- Greater reliance on market forces: Deregulation of some energy markets
- Development of the Strategic Petroleum Reserve
- Strengthened IEA agreements

Macro-economic Trends

The two oil price shocks in the 1970s contributed strongly to the U.S. economic slowdown, as the economy had difficulty adjusting to shifts in the factors of production made necessary by rapid oil price increases.[4] The economic slowdown, in turn, tended to dampen energy consumption. In addition to slower growth rates in the 1970s, the U.S. economy was undergoing profound, and, in some cases, wrenching structural changes, which affected energy use. During the 1980s, there was a significant decline in traditional basic industries (steel, auto, heavy machinery, raw materials), which are typically energy-intensive. The trend toward a service-oriented economy, with emphasis on information services, retail and commercial trade, and final stages of manufacturing and assembly, is expected to continue in the 1990s; it is likely, therefore, that energy productivity gains (i.e., the ratio of constant dollars of GNP per unit of primary energy) will be realized, in part because of the decline in economic importance of energy-intensive sectors of the economy.[5]

Increased Development of Domestic Energy Resources

During the past decade, the U.S. oil and gas industry has made unprecedented efforts to develop and explore domestic gas and oil resources. Between 1973 and 1979, domestic drilling increased by 11% per year (Fig. 3-6). Domestic drilling peaked in 1981 at 90,100 wells (both oil and gas) -- over three times the number in 1971.[6] Before the recent oil price collapse, drilling activity was high compared to past activity. However, disappointing discovery rates, projections of decreasing prices, and excess gas supplies have resulted in a steady decline in drilling since 1981. Other important drilling trends to note include:

- the increasing share of successful gas wells compared to oil wells (e.g., in 1950 there were seven successful oil wells for each successful gas well; during the 1980s, this ratio dropped to about three to one),
- developments in exploratory drilling: 1) between 70 and 80% of all exploratory holes are dry; 2) before 1970, successful oil exploratory wells outnumbered exploratory gas wells by a factor of two to three; during the last 15 years, exploratory gas and oil wells have been equally successful (each accounts for approximately 11-13% of the total number of exploratory wells); and 3) since 1981 gas exploratory drilling has decreased, in part because excess supplies have made it more difficult to market new gas, and
- dramatic decrease in development drilling since the most recent drop in oil prices; in the third quarter of 1986, for example, development drilling was only 38% of 1985 levels.[7]

Despite unprecedented oil exploration, development, and production drilling, U.S. proven crude oil reserves have declined during the last decade, roughly at the rate of 0.6 billion barrels per year. At the end of 1985, proven reserves were estimated at 28.4 billion barrels, a production-to-reserve ratio slightly in excess of nine years. Total additions to reserves have averaged around 2.4 billion barrels per year, however, *new* geologic discoveries have accounted for a relatively small fraction of these additions.[8] The largest share of additions, about 1.4 billion barrels per year, comes from ''revisions and adjustments'' to actual discoveries based on better information and on prospects for increased recovery due to higher oil prices and increased use of secondary and enhanced oil recovery techniques.

The U.S. crude oil production rate has been relatively constant over the past 10 years; from 8.2 million barrels per day were produced in 1976, a peak for the decade of 8.9 million barrels per day were produced in 1984). The slight increase in production (despite declining reserves) can be attributed to in-fill drilling, secondary recovery, enhanced oil recovery, and production by marginal wells. Following the decline in crude oil prices, some production from marginal wells was lost and development drilling decreased significantly. By November 1986, domestic oil production had fallen to 8.5 million barrels per day.

Conservation

The rapid increase in energy prices during the 1970s also spurred improvements in energy efficiency. Gradual improvement in the energy efficiency of energy-using capital has resulted primarily from two factors: 1) significantly lower energy intensities for the stock of new buildings and cars, typically 40-50% lower than the existing stock, and 2) relatively slow turnover rates. In analyzing the persistence of energy-efficiency improvements over time, we must distinguish between behavioral and structural changes. Examples of behavioral responses to increased energy prices include reducing winter thermostat settings, turning off lights, relying on public transportation, and decreasing travel by passenger cars. Structural changes include introducing more efficient new homes and cars as well as retrofitting existing equipment and buildings. Both kinds of changes took place in response to the price shocks of the 1970s. Many of the behavioral changes may be reversible in an era of lower energy prices, but the effects of structural improvements are likely to persist and even grow as the less efficient existing stock is retired.

In transportation, average automobile fuel economy increased from 13.1 miles per gallon (mpg) in 1973 to 17.7 mpg in 1984, a 35% improvement. A study conducted by the Department of Energy (DOE) Office of Policy, Planning, and Analysis found that a relatively small fraction of the reduction in automobile demand resulted from people choosing smaller cars. Instead, most of the improvements in passenger car energy efficiency are structural and unlikely to be reversed (Fig. 3-7).

In the residential sector, average primary energy consumption per household declined by 15% between 1973 and 1984.[9] Delivered energy per household decreased even more substantially during that same period -- by 26% -- primarily because of increased use of electric heating in buildings. (Fig. 3-8).[10]

In the industrial sector, end-use energy consumption per constant dollar of industrial output declined by 28% between 1974 and 1984. The U.S. industrial sector is extremely diverse, although trends in energy use are determined mostly by manufacturing activities, which account for over 75% of industrial energy consumption. The basic materials industries (paper, chemicals, petroleum, steel, and aluminum) use approximately 80% of total manufacturing energy (or roughly 58% of total energy consumption in the industrial sector). Key characteristics of the basic materials industries that will strongly influence future energy consumption patterns include:

1) Tendency of basic materials production to plunge more sharply than the rest of the economy during an economic recession,

2) Shift in product mix away from basic materials because many older products that are materials-intensive have saturated the market or have been replaced by other

products, (e.g., use of plastics rather than metals in automobiles), and

3) Newer products tend to use fewer basic materials, reflecting changes in consumer tastes and needs as well as technological development.[11]

In summary, the shifting product mix and ongoing energy-efficiency improvements in the basic materials industries will most likely depress future industrial energy consumption, although industry will be more affected by the growth rate of the economy than other sectors.

The efficiency improvements in each sector (buildings, industrial, and transportation) can be summarized by looking at energy consumption per constant dollar of gross national product. Between 1973 and 1985, the amount of energy required to produce a constant dollar of gross national product (GNP) declined by 24% (Fig. 3-9). This indicator reflects the overall energy intensity of the U.S. economy. Petroleum and natural gas experienced the most dramatic increases, while the ratio of energy consumed per constant dollar of GNP rose slightly for other energy sources.

Fuel Substitution

Fuel substitution was another major response to the oil price increases of the 1970s. In this section, we highlight two key trends in U.S. energy markets: substitution of other energy sources for oil and increasing reliance upon electricity.

Substitution of other energy sources for oil was particularly dramatic in the residential buildings sector. For example, between 1973 and 1983, oil sales/deliveries in the residential sector decreased from 2.4 to 1.2 quads. This decline was caused by three to four million households that switched away from oil as their main heating fuel, as well as a reduction in oil use per customer of about 35% for the remaining 13 million households that heat with oil.[12] In the power generation market, oil-fired generation declined from 17% of total electricity generation in 1978 to just four percent of the total in 1985, as a result of increases in coal-fired and nuclear-powered capacity.

Electricity's share of delivered energy use in the United States continues to grow (e.g., from 6% in 1960 to 14% in 1984). Electricity is popular in part because its price has increased less rapidly than other fuel prices; real oil and gas prices more than doubled between 1973 and 1983, while electricity prices increased by only about 50%. In the residential sector, growth in electricity demand has also been influenced by appliance saturation levels and changing demographic patterns. During the 1970s, electricity sales to residences increased faster than the number of customers, reflecting growth in electric heating (e.g., from 8% to 19% of all homes between 1970 and 1983) and air conditioning. Population shifts, from the Northeast and Midwest, where oil and gas predominate, to the Sunbelt, where there is a growing demand for electric space conditioning, are also a contributing factor. The increase in electricity use is also related to some of its unique applications (e.g., electronic entertainment, computers, communications and information services, and industrial process applications).[13]

Increased Fuel-switching Capability in Industrial and Power Generation Markets

Increasing oil prices coupled with the gas shortages of the mid-1970s were a strong impetus for the industrial and power generation markets to develop increased fuel-switching capability. Many industrial boilers now have dual-fired capacity, typically the ability to burn either residual oil or natural gas. In the event of a supply disruption or large price increase, those industrial boilers currently burning oil could easily switch to natural gas. The Gas Research Institute (GRI) estimates that 5.7 quads of gas currently used by industrial and electric utilities could by replaced by either residual fuel oil or distillates.[14] This represents 57% of the total gas used by the industrial and power generation market and roughly 30% of U.S. primary gas energy consumption. This fuel switching capability provides flexibility in case of a gas energy emergency. It also tends to put a ceiling on delivered gas prices and contributes to relatively stable gas prices because industrial and electric utility gas users can switch quickly to residual fuel oil at little or no additional cost.[15]

Political Responses to Oil Price Shocks

Significant political responses to the oil price shocks in the 1970s included legislation that encouraged and, in some cases, mandated fuel substitution and end-use efficiency improvements, as well as initiatives to improve energy security and cushion the immediate effects of a supply shortfall (e.g., stockpiling and increased international cooperation). During the early 1980s, greater emphasis was placed on market-based policies, in part a response to problems created by price and allocation controls in energy markets. Efforts to deregulate energy markets were part of a broader social trend toward deregulation (e.g., in the trucking, railroad, airline and telecommunication industries) during this period. However, the legislative initiatives in the petroleum and electricity industry clearly reflect some of the distinctive characteristics of energy markets (e.g., deregulation of only a portion of the production and distribution chain) as well as the lack of consensus on appropriate regulatory reforms.[16]

In 1959, the Mandatory Oil Import Control Program was enacted to protect the viability of the domestic petroleum industry, which was threatened by cheaper foreign oil. The import quota program limited the volume of imports to a fraction of domestic production.[17] In April 1973, (six months before the Arab oil embargo), the Nixon Administration gave unrestricted foreign access to U.S. markets by ending the import quota program. However, government price controls on oil remained in effect until 1981 and kept U.S. oil prices below international levels. After price controls were lifted, U.S. prices increased reached parity with world prices, and the U.S. became fully integrated with international oil markets.

Historically, the gas industry has been extensively regulated by federal and state governments. In 1978, Congress passed the Natural Gas Policy Act (NGPA), which modified the existing gas regulations in several significant areas. The NGPA provided for gradual decontrol of wellhead prices for newly discovered gas; however, interstate pipelines were still to be subject to rate-of-return regulation and could refuse requests to transport gas owned by others. The NGPA was in part a political response to significant natural gas shortages that had developed starting in 1975, as well as the large price discrepancies between the unregulated intrastate and regulated interstate markets.

Attempts to encourage increased competition in electricity generation led to the passage of the Public Utility Regulatory Policies Act (PURPA) of 1978. PURPA required utilities to buy power from "qualified facilities" (QFs) at the avoided cost to the utility of generating the power itself. This obligation to purchase introduced competition in a limited way. PURPA helped stimulate small-scale electricity production, specifically the development of alternative energy -- wind, geothermal, small hydroelectric, and biomass -- and industrial cogeneration projects.

Development of the Strategic Petroleum Reserve

The U.S. Strategic Petroleum Reserve (SPR) was established by the Energy Conservation and Policy Act of 1975, in response to the Arab oil embargo of 1973-74. The reserve was established to provide an emergency supply for use as a last resort in the case of oil supply interruptions. The original intent was to have enough capacity to supply ninety days worth of oil imports. This summer, the President decided to continue filling the reserve beyond the level of 502 million barrels, is approximately equal to 112 days of supply from foreign imports at 1985 import levels and 85 days at projected 1986 levels. To mitigate the immediate effects of a major supply disruption, oil can be withdrawn and distributed from the Strategic Petroleum reserve at a maximum rate of 2.3 million barrels per day for 90 days.[18] Congress has already made appropriations for 750 million barrels of reserve.

IEA Agreements

The International Energy Agency (IEA) was established in 1974 in the aftermath of the first oil crisis. Twenty-one Organization for Economic Cooperation and Development (OECD) states (all OECD nations except France, Iceland and Finland) are members of the IEA. The IEA agreements call for restraints on import demand, accumulation and use of oil reserves, and implementation of a plan for sharing available oil among member nations to equalize the burden of a shortage.[19]

The heart of the IEA crisis-management program is the oil-sharing plan. Oil supplies are to be diverted from relatively less affected member countries to those suffering disproportionate reductions in supplies as the result of an oil supply disruption. Imports are to be reduced by all member nations by the same proportion as the reduction in world oil supply. Each member country is allowed to choose its own methods, typically either demand reduction or release of stockpiles, to achieve the necessary import reduction. In principle, if the reduction in supplies were great enough, those countries with substantial domestic supplies (such as the United States) could be called upon to export oil in order to equalize the shortfalls, although it is not clear that such exports would be politically acceptable.

Recent Changes in U.S. Energy System -- Effects on Vulnerability

The economic and political responses to the energy price shocks of the 1970s have produced a more flexible and resilient energy system in the United States. The U.S. reduced its oil use significantly (from 18 million barrels per day in 1977 to about 15 million barrels per day in 1985) while domestic production remained relatively steady. Thus, U.S. dependence on imported oil was reduced as net oil imports declined by about 30 percent. Potential losses to the U.S. economy from a disruption in oil supplies were also reduced by establishment of the Strategic Petroleum Reserve. Other features of our current energy situation would also mitigate the consequences of an external oil market disruption: 1) excess natural gas production capacity, 2) increased fuel-switching capability in the industrial and power generation markets, 3) improvements in the energy efficiency of the building and transportation stock, and 4) energy emergency preparedness programs and international agreements. However, the recent oil price collapse could reverse many of these trends. Thus, we need to reassess U.S. energy vulnerability in the context of fundamental changes that are occurring in the international energy situation as the result of much lower oil prices.

Notes to Chapter 3

1. In looking at consumption by source, note that total energy consumption includes energy losses associated with generating and distributing electricity. The losses are distributed based on each sector's electricity consumption.
2. See Energy Information Administration (EIA), *Energy Conservation Indicators 1984*, p. 7.
3. One quad equals 10^{15} Btu.
4. H. Rowen and J. Weyant, *The Oil Price Collapse and Growing American Vulnerability*, p. 5.
5. U.S. Department of Energy, Office of Conservation *FY 1988 Energy Conservation Multi-Year Plan*, July 1986.
6. Most wells contain both oil and natural gas, but they are characterized by the predominant form of production.
7. ''Exploratory drilling'' means searching for new resources, while ''development drilling'' means drilling to produce or to increase production of a previously discovered hydrocarbon accumulation. See EIA, *An Economic Analysis of Natural Gas Resources and Supply*, DOE-EIA-0481, 1986, p. 12.
8. Extracted from remarks by Kenneth Davis at a Council on Alternate Fuels conference on ''The Changing Oil Industry'', December 3, 1986.
9. S. Meyers, *Energy Consumption and Structure of U.S. Residential Sector*, Lawrence Berkeley Laboratory, 1986.
10. Primary energy consumption includes losses in electricity generation, while delivered (or end-use) energy reflects energy actually purchased on-site by households.
11. CERA, *Energy Demand: Demand or Rebound, Industry.*
12. S. Meyers, *Energy Consumption and Structure of U.S. Residential Sector*, 1986.
13. U.S. Department of Energy, Office of Policy, Planning and Analysis,*The Future of Electric Power in America: Economic Supply for Economic Growth*, p. 2-2.
14. H. Linden, *Case for a Methane-Intensive Energy Economy*, presented at California Energy Commission conference, ''California: Setting New Directions for Natural Gas'', September 1985.
15. Arthur Anderson and Company and Cambridge Energy Research Associates, *Natural Gas Trends,* 1986, pp. 1, 11.
16. EIA, *Competition and Other Current Issues in the Natural Gas Market*, DOE-EIA-0489, June 1984, p. v.
17. D. R. Bohi and W.D. Montgomery, *Oil Prices, Energy Security, and Import Policy*, Resources for the Future, 1982, p. 1.
18. Department of Energy, Office of Energy Emergencies, ''Energy Emergency Preparedness: Building Energy Security Against Future Supply Disruptions'', January 9, 1987. Drawdown rates are lower after 90 days: 1.8 MMBD for the next 30 days and 0.7 MMBD for the next 60 days.

19. D.R. Bohi and M.A. Toman, ''Oil Supply Disruptions and the Role of the International Energy Agency'', *Energy Journal 7:2*, 1986, pp. 37-50.

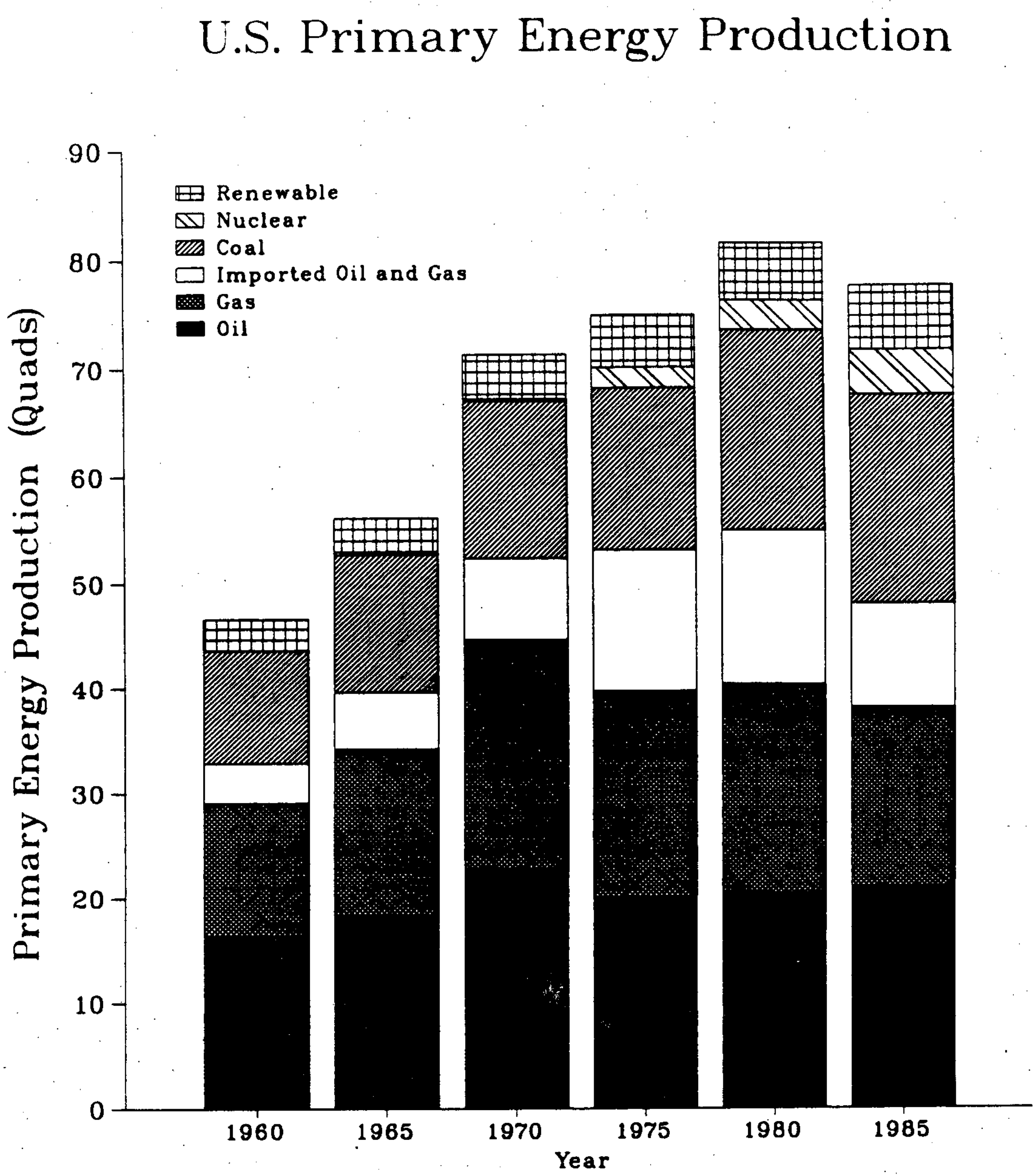


Figure 3-1. Primary energy production in the United States.

Source: Energy Information Administration, *Monthly Energy Review*, August 1986. Department of Energy, *The WOIL/ Fossil National Energy Model*, September 9, 1986.

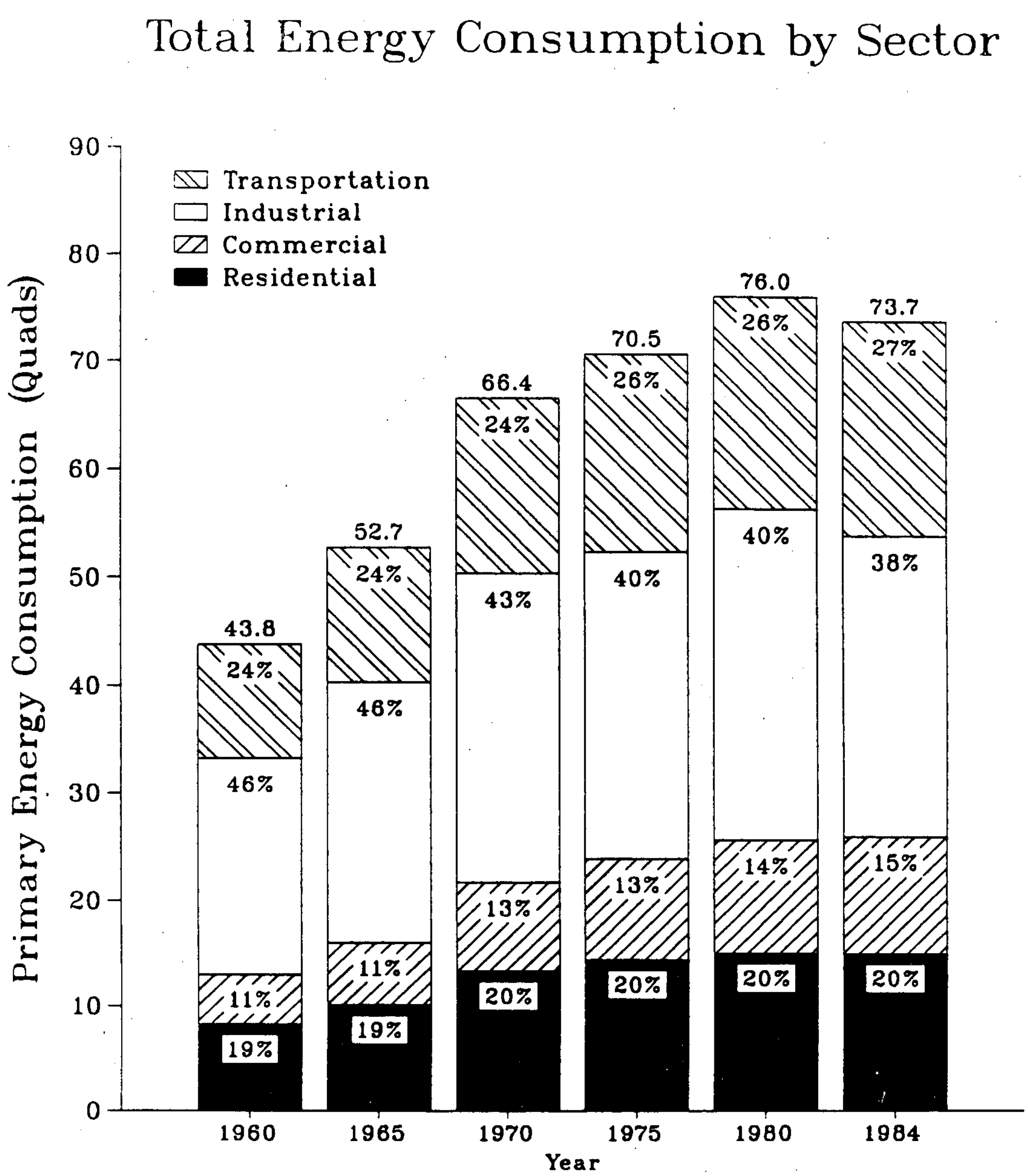


Figure 3-2. Total U.S. energy consumption by sector.

Source: Energy Information Administration, *Energy Conservation Indicators: 1984 Annual Report*, p. 7.

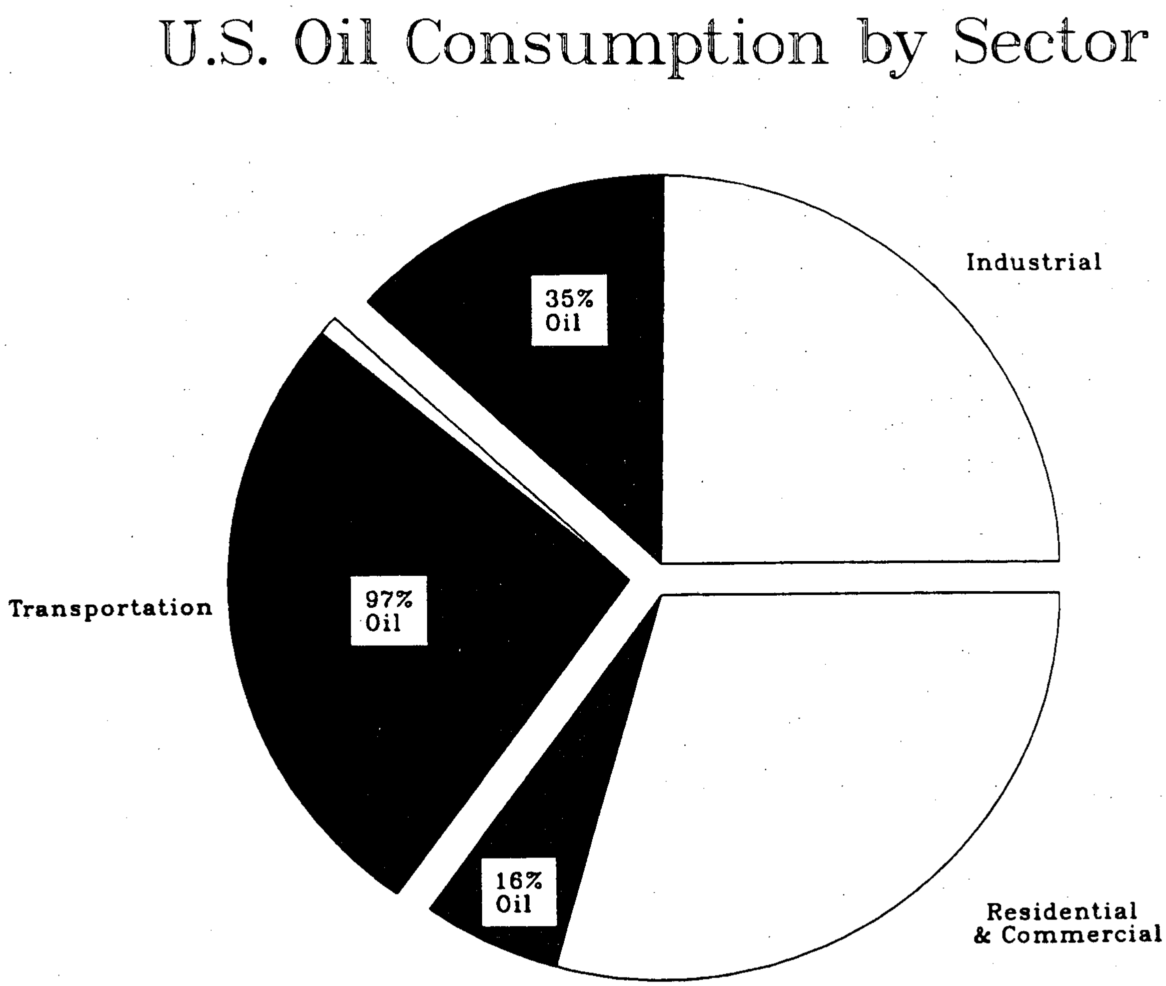


Figure 3-3. U.S. oil consumption by sector.

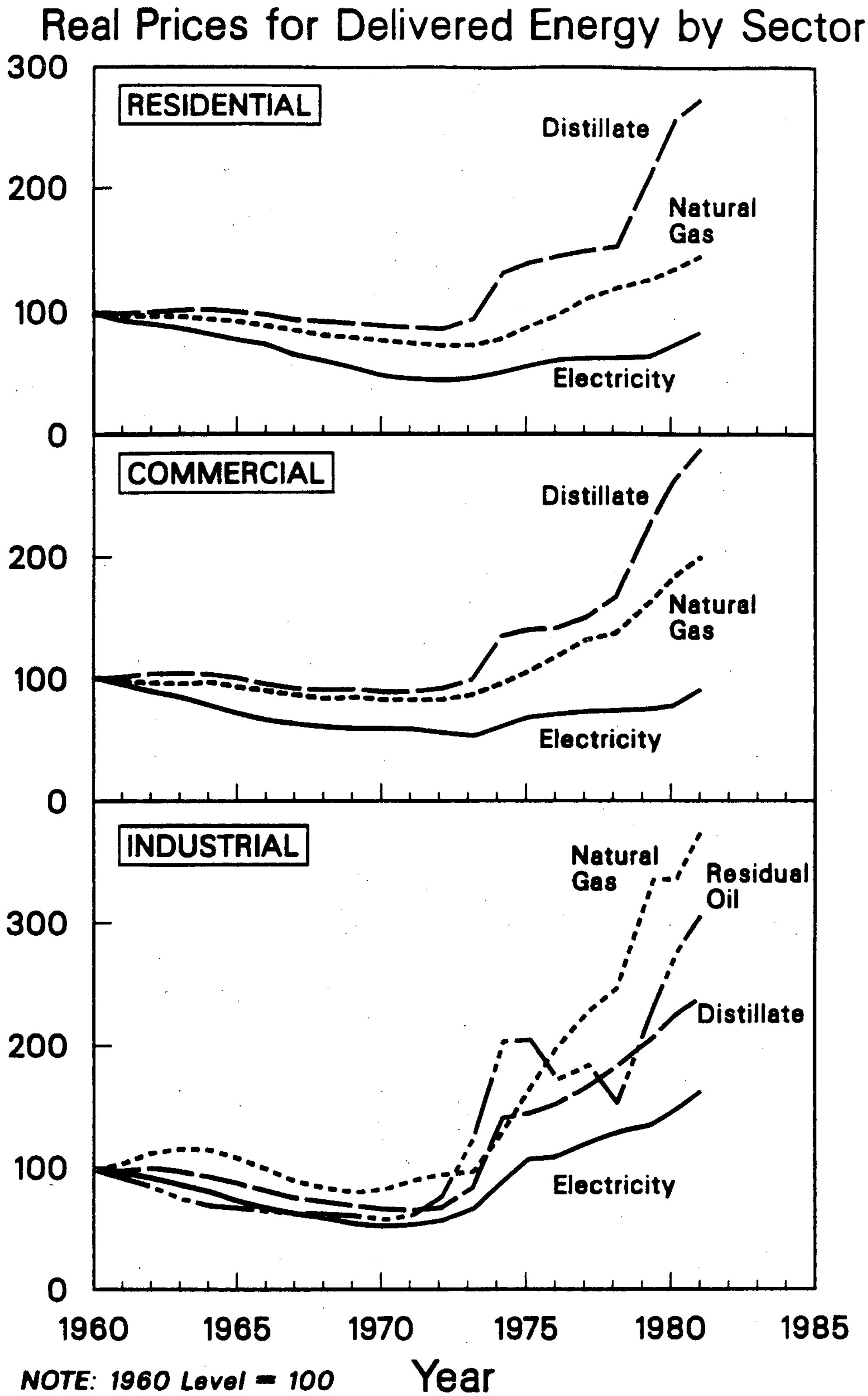


Figure 3-4. Real prices for delivered energy by sector.
Source: Department of Energy, *Future of Electric Power*

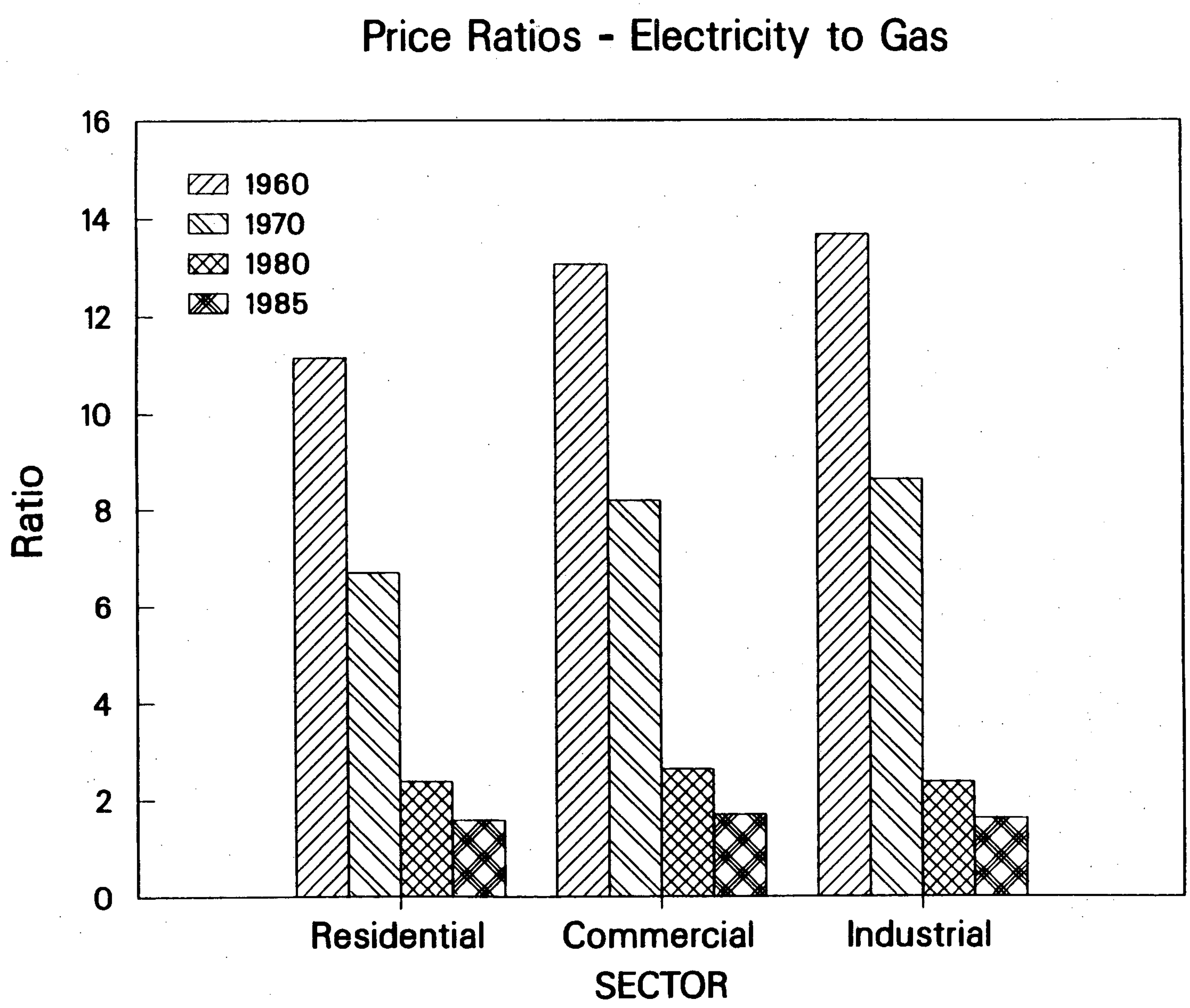


Figure 3-5. Electricity-to-gas price ratios for residential, commercial, and industrial sectors.

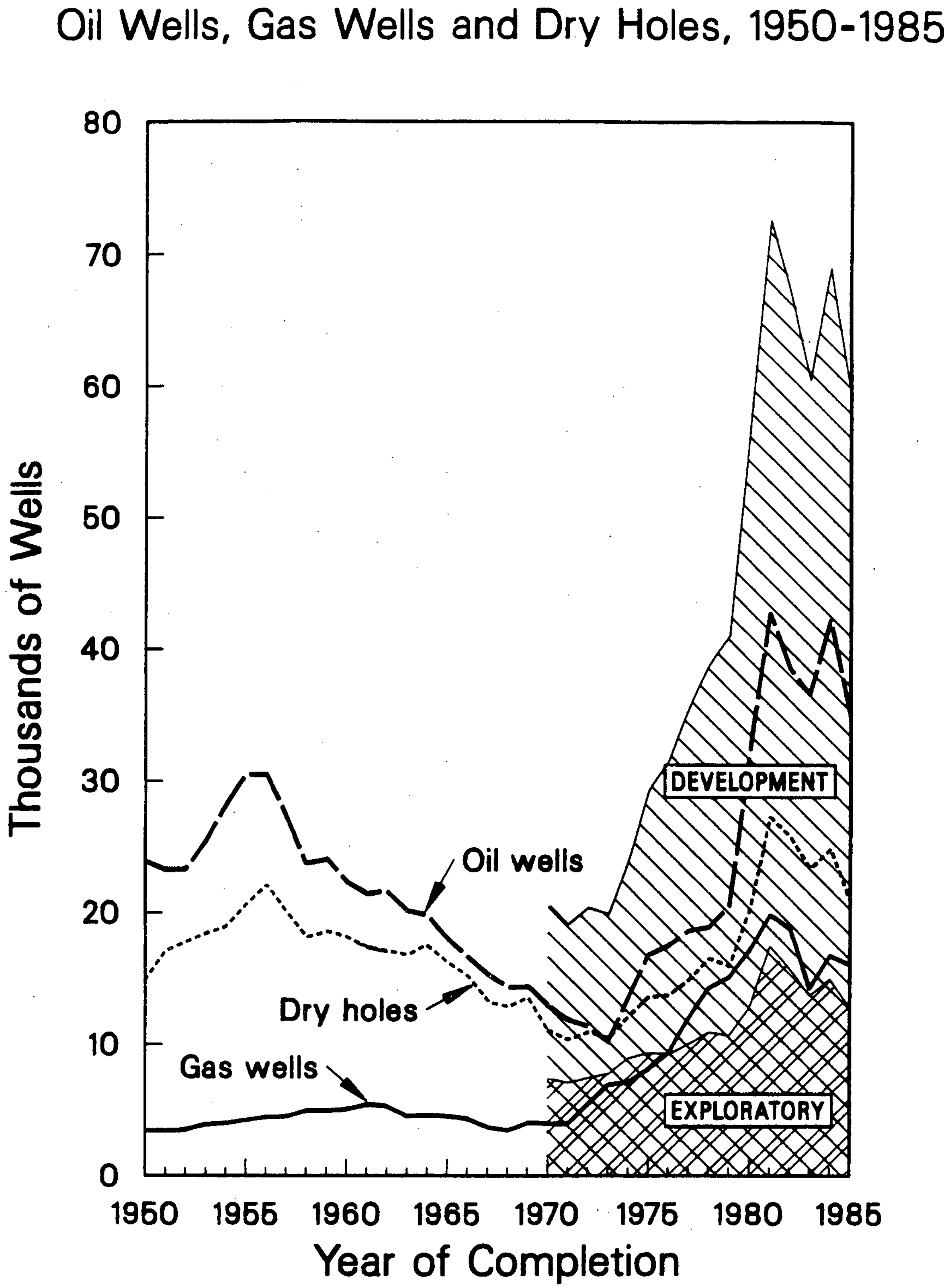


Figure 3-6. Trends in U.S. domestic gas and oil drilling. Number of exploratory and development wells drilled (both oil and gas) since 1970 is shown by shaded area.

Source: Energy Information Administration, *An Economic Analysis of Natural Gas Resources and Supply,* DOE/EIA-0481, October 1986.

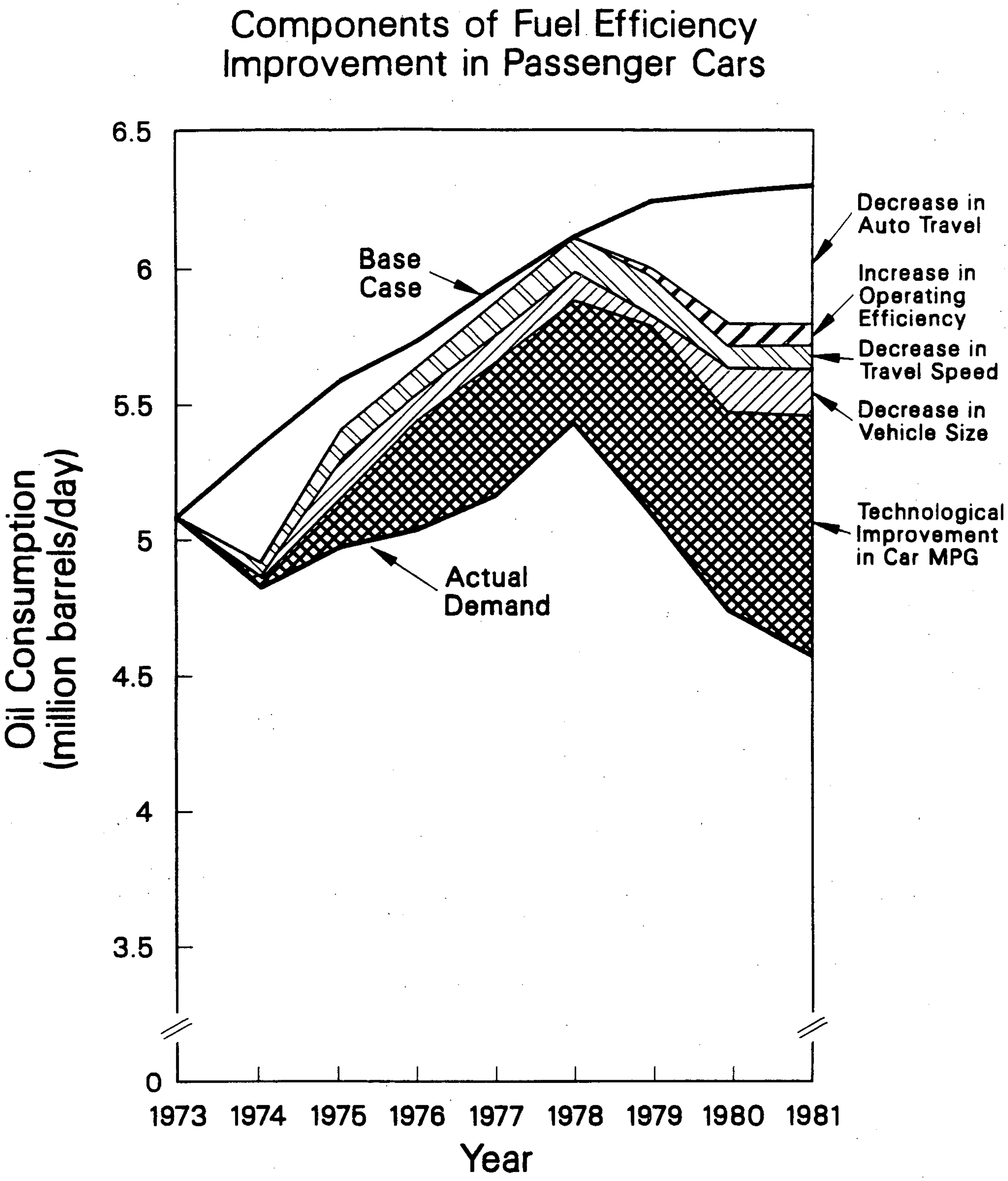


Figure 3-7. Components of fuel efficiency improvement in passenger cars.

Source: C. Difiglio and B. McNutt, *Causes of Reduced Automobile Fuel Demand and its Implications for Consumers*, Office of Policy, Planning and Analysis, Department of Energy, January 1982.

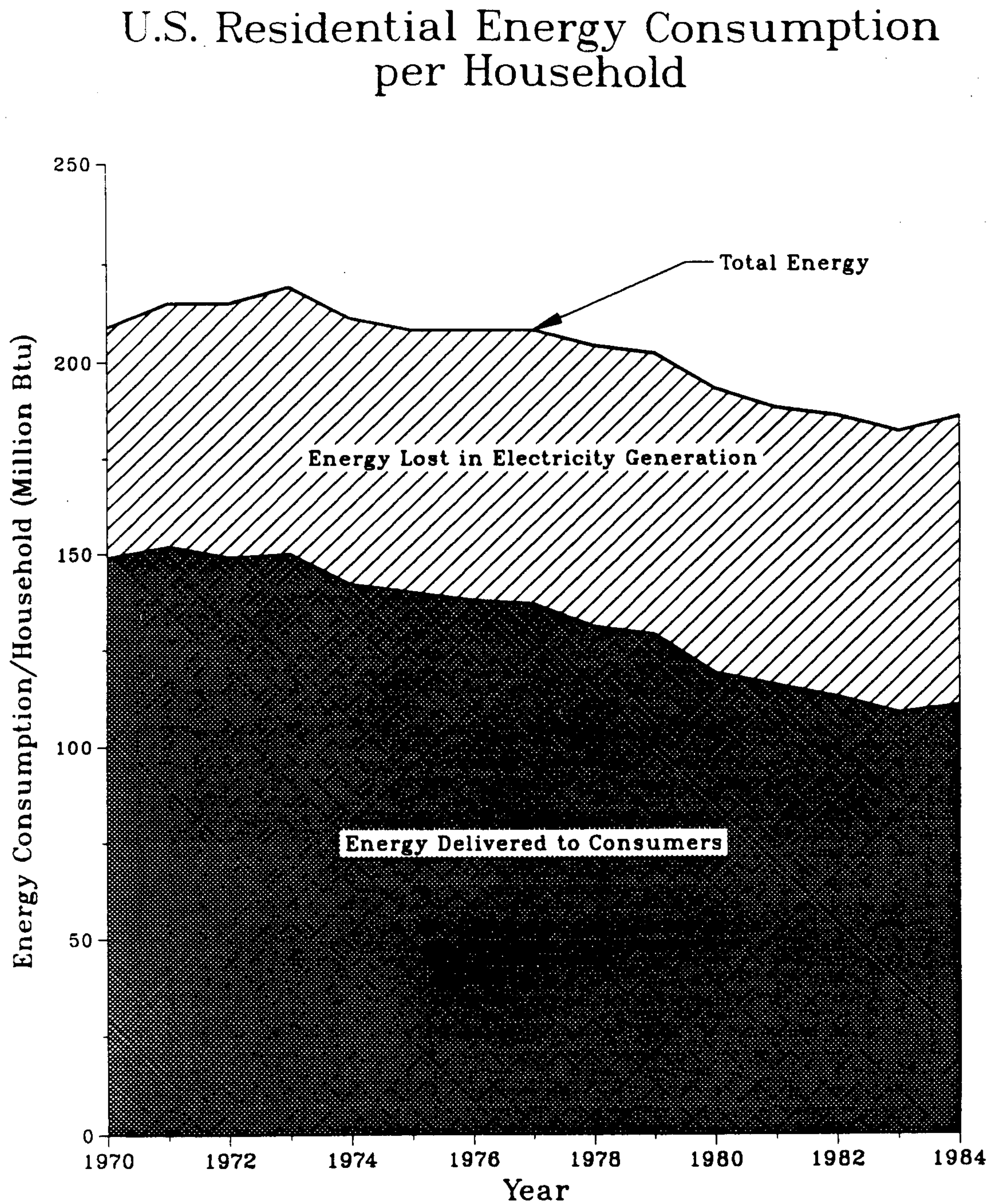


Figure 3-8. U.S. residential energy use per household. Energy consumption has been adjusted for the effects of weather.

Source: S. Meyers, *Energy Consumption and Structure of the U.S. Residential Sector: Changes between 1970 and 1984*, LBL- 21190, March 1986.

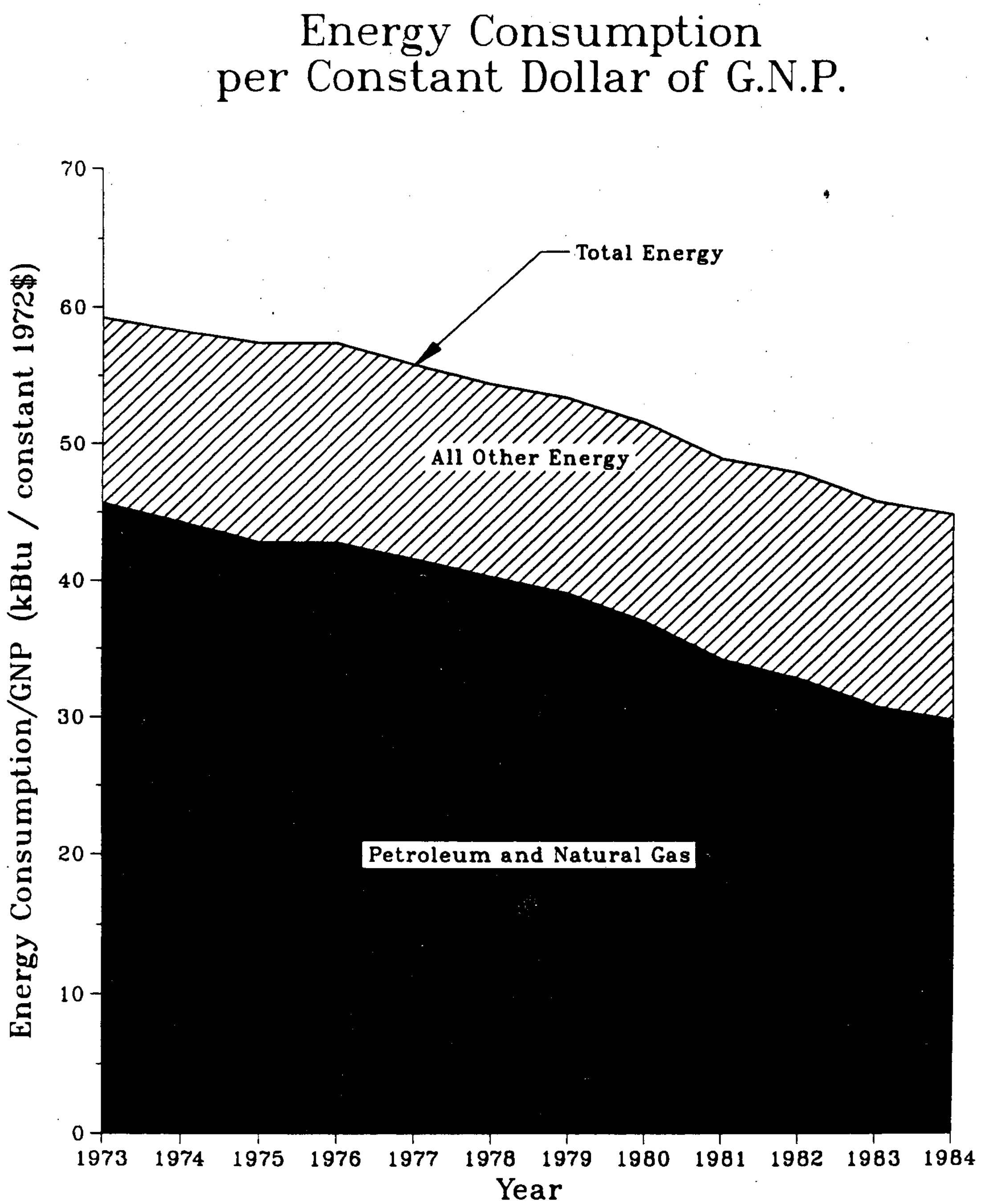


Figure 3-9. U.S. energy consumption per constant dollar of gross national product. The ratio of petroleum and natural gas consumption per GNP fell at an annual rate of 3.8 percent between 1973 and 1984, accounting for much of the decrease in energy intensity.

Source: Energy Information Administration, *Energy Conservation Indicators: 1984 Annual Report*, p. 6, 59-60.

Chapter 4

U.S. AND INTERNATIONAL ENERGY OUTLOOK DURING THE 1990s

This chapter discusses the energy supply and demand outlook during the next decade, focusing principally on economic and political factors that affect the world oil market. We begin with a brief summary of recent developments in the world oil market. We then review some of the major effects of lower crude oil prices on the U.S. economy and energy industries and discuss the short-term outlook for oil prices (1986-1988). Next, we analyze major trends in oil supply and demand from the present to the 1990s and present two possible world energy outlooks that are linked to higher and lower oil price trends. We conclude with a discussion of the uncertainties and hazards of forecasting future trends in energy markets.

Recent Developments in the World Oil Market

World oil prices collapsed in early 1986. oil price shocks of the 1970s. On average, the price of oil in the first nine months of 1986 was half of what it had been in 1985 and spot prices sank to a low of $8-9/barrel during July 1986. In real terms, oil prices (adjusted for inflation) have returned to pre-1973 levels. The immediate impetus for falling crude oil prices was a significant increase in OPEC production, (approximately three million barrels per day during the fourth quarter of 1985) which occurred after OPEC's December 1985 meeting, at which the organization announced its intention to increase its market share. As discussed in Chapter 2, several fundamental market and political forces were at work, specifically weak demand for oil, growth in non-OPEC oil supplies, substantial unused production capacity, and OPEC's loss of market share. These forces created a supply/demand situation in which it was no longer possible for a non-unified OPEC to sustain $25-28/barrel prices. (i.e., $25-28/barrel).

The 1986 price collapse has had a significant effect on world oil production. During the first half of 1986, oil exporting countries and oil companies were forced to make traumatic adjustments as they felt the full effects of the price collapse. For OPEC nations, the increased output was not sufficient to offset lower prices, so annual oil revenues declined by $40-50 billion. Many non-OPEC oil-exporting countries faced revenue cuts of up to 50 percent. Crude oil prices were especially volatile and it became difficult to determine actual prices. In August 1986, OPEC reached a temporary agreement that reinstituted production quotas for individual countries and also reduced the cartel's production by several million barrels per day.[1] More significantly, for the first time, most of the major non-OPEC exporters indicated that they too would exercise some degree of production restraint. For example, Mexico agreed to cut production by about 150 thousand barrels per day, Norway agreed to reduce exports by 70-80 thousand barrels per day, and the USSR said that it would reduce exports by about 100 thousand barrels per day. Crude oil prices then stabilized around $14-16/barrel.

With the winter heating season approaching, OPEC agreed at its October 1986 meeting to extend the accord reached in August. Later that month, Sheik Ahmed Yamani was replaced as the oil minister of Saudi Arabia. This signaled major changes in Saudi policy. After Yamani's removal, the Saudi's announced their intention to abandon net-back pricing and sought to re-establish crude oil prices at about $18 per barrel. Prices have moved up to $16-19 per barrel in early 1987. However, the viability of OPEC's most recent agreement will depend on oil companies' decisions about whether to increase or decrease their inventories, production policies of non-OPEC major oil producers and of Iraq (which did not sign the agreement), the impact of a falling dollar on oil demand, and the willingness of other OPEC nations to produce at their allowed quota and sell at official prices, particularly as demand slackens with the end of the heating season.

Major Effects of Lower Oil Prices

The large decline in crude oil prices reflects a shift in political and economic power from sellers to buyers. In aggregate, oil-importing nations have benefitted from a wealth transfer at the expense of oil-exporting countries. The reduced revenue requirements of oil importers constitutes a stimulus to economic growth and lower inflation, especially if low oil prices are sustained for several years. A recent Data Resources Inc. (DRI) study concluded that the drop in oil prices would clearly benefit the U.S. economy, leading to a modest improvement in economic growth in 1987 and 1988, but would not generate a boom.[2] In relative terms, DRI found that the positive impact on the U.S. economy of the price collapse would be smaller than the negative effects caused by the rapid price increases that occurred during the mid-1970s. Factors that explain this shift in the impact of oil prices include:

- The U.S. economy is less energy-intensive than it was in the early 1970s (e.g., to produce $1 billion in real GNP requires 21 Quads today compared with 26 Quads of energy in the early 1970s).
- Oil imports currently supply a much smaller fraction of U.S. energy demand; most of the benefits of lower oil prices are paid for out of the profits of domestic oil companies.
- Unfavorable price shocks tend to retard economic growth more than favorable trends boost it.
- Oil companies react quickly to the negative impacts of low oil prices, but consumers take longer to adjust their spending patterns.[3]
- The price shocks of the 1970s made some inefficient energy-using equipment obsolete; while the recent oil price collapse actually ''rehabilitated'' some fraction of the old capital stock (e.g., a car that gets 14 MPG is no longer as uneconomic as it was).

A recent Energy Information Administration (EIA) study estimated that real GNP would increase by 1-2%, disposable income would increase by 2%, while unemployment would be reduced by around 0.5 percent, and the Federal Deficit reduced by roughly 10 percent if oil prices were $10/barrel lower each year through 1995 compared to EIA's base case projection (Table 4-1).[4]

Table 4-1

Impact of Lower Oil Prices

Indicator	1986-1990			1991-1995		
	EIA[a] Base Case	Low Oil[b] Price Case	Difference	EIA Base Case	Low Oil Price Case	Difference
Real GNP, Average[c] Level (Bils. '72$)	1913	1948	1.8%	2237	2260	1.1%
Unemployment Rate, Average Level (%)	6.9	6.3	-0.6	6.8	6.5	-0.2
Employment (Millions)	112.7	113.8	1.1	119.5	120.0	0.5
Real Disposable Income (Bils. '72$)	1286	1316	2.3%	1457	1488	2.1%
Fed. Deficit (Bils.$)	118.1	101.8	13.8%	102.2	91.0	11.0%

Notes to Table 4-1

[a] Source: Energy Information Administration (EIA), *Annual Energy Outlook: 1985*, Feb. 1986.

[b] Based on simulation results using the DRI Quarterly Model of the U.S. Economy.

[c] Low Oil Price Case assumes that $10/barrel is subtracted from Base Case oil price in each year.

Source: Energy Information Administration (EIA), *Impact of Lower World Oil Prices and Alternative Energy Tax Proposals on the U.S. Economy 1985*, April 18, 1986, p. ix.

Although lower oil prices are clearly beneficial to the nation as a whole, certain regions of the country and specific industries are affected adversely. Several major oil producing states -- Texas, Louisiana, Oklahoma, Alaska -- are suffering severe fiscal problems caused by significant reductions in state revenues from income, severance, and other taxes. Unemployment rates in these states are well above the national average, in double digits in most cases. In addition, the domestic petroleum industry is economically depressed:

- the Hughes Tool Company rig count has fallen from about 2000 rigs in 1985 to fewer than 800 rigs by mid-1986, a 62% decrease,
- oil companies have reduced capital expenditure rates by about 30% since October 1985,
- independent producers increasingly have to finance new exploration and development projects out of internal cash flows, because funds from private investors have declined by 80% during the last few years, from $4.0 billion in 1981 to $0.8 billion in 1985,
- employment in the oil and gas extraction industries has fallen 21% since October 1985, a total of 127,000 jobs lost (Fig. 4-1).[5]

Given the long lead time for developing new resources, the full effects of current cutbacks in oil and gas exploration and production will not be felt for years to come. Lower capital expenditures and decreased drilling activity will certainly lower reserve additions and domestic production. However, the short-term effects on domestic crude oil production are already quite noticeable. U.S. crude oil production was about 300 thousand barrels per day lower in 1986 than in 1985, a 3.4% decline, while fourth quarter production was 6.7% less than during the same period in 1985.[6] Presumably, some of the production loss, especially in the fourth quarter, is caused by the decline in development drilling. In addition, some high-cost U.S. production, primarily stripper wells, but also enhanced oil recovery projects, and oil wells with unusually high operating costs, has been shut down.[7] Stripper wells produce about 1.3 MMBD, and an estimated 300-400 thousand barrels per day could be lost if oil prices stay around $15/barrel (Fig. 4-2). Under current laws, stripper wells can be shut in temporarily for up to one year and then must either be reopened or permanently sealed, primarily because of safety and environmental concerns.[8]

Low oil prices will also have major international repercussions. A sustained period of low oil prices will eventually lead to significant increases in world oil demand, and a reduction in oil production from high cost regions of the world (principally North America), which will begin to rely again on lower cost oil from the Persian Gulf.[9] In the near term (through 1989), lower prices will probably have a greater effect on oil production than on demand, because many conservation practices adopted after the price increases of the 1970s have become permanent. By 1992, it is estimated that Britain's North Sea production could be as much as 400 thousand barrels per day lower compared to production levels at a price of $23/barrel.[10] In addition, low oil prices pose problems for major debtor nations that are large oil producers (e.g., Mexico); in contrast, the burden on developing countries that depend on oil is reduced.

Short-term Outlook for Oil Prices

Most analysts believe that oil prices will continue to be unstable, particularly in the near-term. For example, EIA, in its study of the impact of low world oil prices, assumed that it was equally likely that world oil prices would average either $10, 15, or $20 per barrel in 1986.[11] A study by DOE's Office of Policy, Planning and Analysis (OPPA) concluded that there was a high probability (greater than 50%) of $15 per barrel oil prices through 1988, with lower probabilities (i.e., 10-20%) of oil prices at $10 or $20 per barrel (Table 4-2).[12]

Table 4-2

Uncertainty in Near-Term Oil Prices

	Assumed Oil Price ($1986/barrel)		
	$10	$15[a]	$20
OPEC Oil Production (MMBD)[b]			
- 1986	20	19	<18
- 1988	23-25	22	19-20
OPEC Revenues (billion 1985 $)			
- 1986	54	73	90
- 1988	66	82	92
Likelihood of OPEC Production Agreement	--	High; Maybe not Necessary	Low
Factors needed to sustain assumed price	• OPEC Inability to agree on production quotas		• Rapid Increase in Demand • Decrease in non-OPEC production
Probability	10-20%	> 50%	10-20%

[a]Range of $13-$17 per barrel
[b]Including 1.1 MMBD of Natural Gas Liquids
[c]Low likelihood of agreement because of low OPEC production level
Source: Department of Energy, Office of Policy, Planning and Analysis, ''Low World Oil Price Scenarios (draft)'', May 1986.

The main reason for these large uncertainties in near-term prices is that demand cannot increase quickly enough during 1986-88 to absorb even very inexpensive oil that could be made available if unused production capacity, were put into operation.[13] In the short term, world oil production is likely to decline very slowly in response to low oil prices, because direct lifting costs (i.e., short-run marginal costs of production) from most existing wells are below $5 per barrel (Table 4-3). Thus, near-term prices are dependent largely on OPEC production policy, particularly the decisions of Saudi Arabia.

Table 4-3

Average Crude Oil Production Costs: 1984
($/Barrel)

Region	(1) Direct Lifting Costs	(2) Direct Finding Costs[a]	(3) Total Direct Costs	(4) Royalties and Producing Taxes	(5) Total Costs
United States	4.35	8.93	13.28	2.69	15.97
Canada	3.94	5.39	9.33	3.16	12.49
OECD Europe	2.97	4.19	7.16	1.25	8.41
Africa	2.87	4.37	7.24	2.92	10.16
Mideast	1.97	3.63	5.60	5.37	10.97
Other Eastern Hemisphere	4.08	8.98	13.06	5.27	18.33
Other Western Hemisphere	3.43	6.68	10.11	3.93	14.04

Notes to Table 4-3:

Column (3) is equal to sum of columns (1)+(2)

Column (5) is equal to sum of columns (3)+(4)

[a]Exploration costs (expended and capitalized) for 1981-1984 divided by oil and gas reserve additions due to extensions and discoveries.

Source: Energy Information Administration, "The Impact of Lower World Oil Prices and Alternative Energy Tax Proposals on the U.S. Economy", April 18, 1986, p. 6.

Energy Supply/Demand Outlook during the 1990s

In the next two sections, we identify some of the key underlying forces that are expected to shape the energy demand and supply outlook in the U.S. and internationally during the 1990s. We focus on factors that affect the world oil market. Much of this discussion is based on the most recent energy forecasts by government agencies, oil companies, and industry groups. In particular, we draw upon projections made by the Department of Energy's Office of Policy, Planning, and Analysis, the Energy Information Administration, the Gas Research Institute, Chevron Corporation, Ashland Oil

Company, and LBL's International Energy Studies Group (see Appendix A).[14]

The U.S. Supply/Demand Outlook

Figure 4-3 shows the 1985 U.S. petroleum supply/demand balance. Transportation accounts for over 60 percent of total petroleum demand, while industry's share is about 26 percent. Domestic oil production was able to meet about 70 percent of this demand in 1985. During the next decade, the U. S. economy is expected to grow by 2-3% per year, while growth in primary energy demand is expected to average just over 1% annually. However, growth in oil demand will be relatively flat, about 50% of the rate of growth in energy demand, for the following reasons:

- demand for motor fuel is not expected to increase much because increases in fleet fuel efficiency are projected to offset increases in vehicle travel (e.g., the average fuel efficiency for new U.S. cars is about 26 miles per gallon (mpg), while the current fleet average is 17 mpg),
- the industrial sector's oil demand will stay constant because of low growth in energy-intensive industries and continued impact of efficiency investments,
- most of the growth in oil demand will come from rising diesel fuel consumption by light and heavy trucks and increased use of residual fuel oil as the marginal fuel in power generation.

By the year 2000, U.S. domestic oil production is projected to be more than two million barrels per day lower than current levels. Reasons for the expected decline include:

- relatively low world oil prices that tend to discourage exploration and development activities,
- marked decline in Alaskan oil production after 1987 (production from Prudhoe Bay is projected to decline from the current level of 1.7 MMBD to 0.7 MMBD by the year 2000), and
- expected decline in older domestic fields in the 48 contiguous States.

International Supply/Demand Outlook

Figure 4-4 summarizes the world oil demand/supply situation as of 1985, and highlights regions where oil consumption far exceeds production, (e.g, Japan, Western Europe except for Great Britain and Norway). Between now and the 1990s, oil demand is expected to increase relatively slowly in Western industrialized nations (i.e., OECD countries), even at low oil prices. Chevron, for example, predicts that U.S., Japanese, and Western European oil consumption each will grow by about 0.5-0.6% per year until 2000, while the Gas Research Institute (GRI) expects oil demand in the industrialized nations to increase by 0.9% per year between 1985 and 1995.

Oil demand will be relatively flat in the OECD nations because of the following factors:

- improvements in the efficiency of oil-using capital stock,
- shift of energy-intensive basic materials industry to LDCs,
- substitution of other fuels for oil (e.g., nuclear- and coal-based electricity generation),
- fierce inter-fuel competition (natural gas and coal vs. oil) that will limit switching to oil in industrial and power generation markets,
- and high prices for final petroleum products as a result of government-imposed taxes, even at low oil prices, which will tend to depress demand.

In contrast, oil demand is expected to increase significantly in less developed countries (LDCs), even at relatively higher oil prices. However, much less is known about the structure of energy and oil markets in these countries than in industrialized nations; not surprisingly, there is less consensus on predicted oil demand growth in those countries. The LDCs are a diverse group and include newly-industrialized countries (e.g., South Korea, Taiwan), oil-importers and exporters, members of OPEC (e.g., Venezuela, Nigeria), as well as the People's Republic of China (see Appendix B). Despite widely differing economic/political systems and levels of development, LDCs share one important feature that distinguishes them from industrialized countries: they are still undergoing industrialization and urbanization. It is these two forces, industrialization and urbanization, that will continue to place upward pressure on commercial energy demand. For example, urban population growth has led to increased demand for cooking and transportation fuels. Typically, in cooking, kerosene is the fuel choice among urban lower-income groups, with use increasing with income. Among the higher-income urban population, kerosene is displaced by liquified petroleum gas (LPG) and/or electricity.

LBL's historical analysis of demand growth in LDCs indicates that oil and energy consumption has increased in both vibrant and stagnant economies and that aggregate oil consumption increased through periods of rising and falling prices (see Appendix B, Table B-3). Growth in oil consumption slowed to 1-2%/year after 1978 compared to 7-9%/year in the early 1970s. Forecasts of lower real oil prices should help spur economic growth (and oil demand) in oil-importing LDCs, although falling commodity prices and growing foreign debt will hamper growth in some countries. In addition, constraints on available capital in LDCs will tend to increase growth in oil demand, as they limit investment in capital-intensive, non-oil energy technologies. LBL's International Energy Studies Group projects that LDC oil demand will reach 24 MMBD by the year 2000, increasing at about 3.8% per year (Table 4-4). The LBL forecast is significantly higher than other projections -- it is at least four million barrels per day more than Chevron is projecting for these same countries by 2000. This discrepancy illustrates the large uncertainties that exist in projections of oil demand in LDCs. The world oil market will tighten much sooner if LDC oil demand increases at rates close to the LBL projection.

Table 4-4

LDC Oil Demand Forecast[a]
(Million Barrels Per Day)

	1985	1990	2000
Asia	4.06	4.5	6.3
China	1.76	2.3	3.5
Africa	1.72	1.9	2.8
Latin America	4.43	5.4	8.1
Middle East	1.98	2.3	3.2
TOTAL[b]	13.95	16.2	24.0

Notes to Table 4-4:

Source: "BP Statistical Review of Energy" for 1985 data; Lawrence Berkeley Laboratory, International Energy Studies Group for projections.

[a] The LBL forecast by region is based on detailed individual forecasts for 13 study countries in Asia, Latin America, and Africa. In this forecast, real oil prices are assumed to be $20/barrel in 1990, increasing steadily to $34 dollars/barrel by 2000.

[b] Totals may be slightly different from the sums because of rounding errors.

Barring any major new discoveries, crude oil supplies from non-OPEC producers will most likely decline by at least two or three million barrels per day during the next fifteen years because non-OPEC producers have limited reserves and higher production costs than OPEC producers (see Table 4-5).[15] In North America, increased crude oil production from our neighbors, Mexico and Canada, will somewhat offset decreased U.S. production. During this period, crude oil production from Communist countries is expected to remain at or above current levels, as increases from China offset declines in the Soviet Union and Eastern Europe. In addition, development of gas reserves and reduced flaring in less developed countries is expected to result in significant increases (about 2%/year) in the production of natural gas liquids (NGL). Non-communist NGL production may reach five MMBD by 2000, mostly from five producers: the United States, Saudi Arabia, Algeria, Canada, and Mexico.

Table 4-5

Projected Petroleum Supply from non-OPEC Producers

Country	1985	1990	2000
United States	8.93	8.2	6.2 - 6.3
Canada	1.46	1.1	1.5 - 1.55
Mexico	2.73	3.0	3.6 - 4.2
Western Europe (mostly North Sea)	3.83	3.7 - 3.8	2.8
Other Non-OPEC	5.62	5.7	5.7
NGL Production	2.68	2.6	2.4
	25.25	24.3 - 24.4	22.2 - 23.0
China	2.48	3.0	3.0
USSR	11.25	11.2	11.0
E. Europe	0.37	---	0.25

Sources: Chevron Corporation, ''World Energy Outlook," June 1986;

GRI, ''1986 GRI Baseline Projection of U.S. Energy Supply and Demand,'' 1986.

Two Possible Scenarios: High and Low Oil Price Trends

Forecasting future oil prices is particularly difficult. Oil prices have stubbornly refused to behave as predicted during the last 15 years, despite fairly strong consensus at particular points in time on their likely direction. Figure 4-5 shows the differences between consensus oil price forecasts at particular historical junctures (vintages I through V) and actual price paths.[16] For example, after the second oil price shock (vintage IV 1980-82), *real* oil prices were predicted to reach $50 to 55 per barrel by the mid-1990s in most forecasts (increasing by 2-3% each year, in real terms). These forecasts were based on the assumption that world oil demand would bump up against supply constraints created by OPEC producers unwillingness to produce at capacity. However, this forecast did not anticipate the downward effects on energy and oil demand of the world-wide economic recession, relative appreciation of the U.S. dollar, conservation, and substitution.[17] It is impossible to predict accurately the future path of oil prices (except within very wide bounds), because of large uncertainties in the key assumptions upon which price forecasts are based. Moreover, in discussing public forecasts of future oil prices, we must be aware of a paradox associated with forecasts of rapidly rising oil prices. Producers may decide to limit production in response to a prediction that oil prices will rapidly incrase. Although oil prices have often increased much faster than the interest rate, it is impossible to forecast future increases in the price of oil that may result from producers' reactions to various predictions. Oil producers with zero or negative inventory costs for oil, for example, have an incentive to postpone or limit current production if they believe a forecast that predicts rapid increases in the price of oil. If they change their current production schedule on this basis, the supply/demand balance will be altered, making the rapid price increase occur earlier than predicted. In addition, other producers with zero or negative inventory costs may decide to reduce their production, once there is concrete evidence of the start of a rapid increase in oil prices. Thus, it is not an aberration or a correctable failure in forecasting methodology that particularly rapid increases in the price of oil were not generally anticipated. More important, we must expect and plan for the possibility that rapid increases in the future price of oil may well occur at times that are not generally anticipated.

Given these caveats, we now discuss recent forecasts of future trends in the world oil market; these forecasts were developed during and after the oil price collapse of early 1986. As in previous periods, these forecasts show similar views on the future direction of oil prices. In Figure 4-6, we show high and low oil price forecasts of various oil companies, the Department of Energy (DOE), and the Gas Research Institute, along with our estimate of price ranges for low and high oil price scenarios (the shaded area). The price trends are presented as relatively smooth paths; however, it is likely that actual price trends will be more erratic and cyclical than the smooth rates represented in the projections. For example, Chevron also developed a scenario characterized by cyclical oil price swings, which could be caused by lagged response to business cycles or politically motivated supply disruptions. Moreover, we can not rule out the possibility of one or more future oil price collapses.[18]

The high oil price scenario hinges on the following key assumptions:

- moderate and improving economic growth rates over the next 15 years (2-3%/year),
- that OPEC is able to maintain some degree of cohesion and agreement on production and pricing levels,
- and that these price levels will not suppress demand or stimulate large-scale exploration in high-cost frontier areas.

Events and policies that would contribute to the likelihood of the low oil price scenario include:

- OPEC producers determination to maintain market share through higher production, even if it means lower prices,

- oil-producing nations with large reserves decide to increase production to meet rising oil demand in order to restrain price increases,
- demand for oil does not respond strongly to the current low price regime,
- and continuation of problems with alternative fuels, like coal and nuclear, which reduce their contribution.[19]

Over time, low oil prices will stimulate demand, which will place upward pressure on prices; the key question in this scenario is how long lower prices could be sustained rather than whether they can be sustained.

By the year 2000, oil prices are projected to be in the $28-34/barrel range under the high oil price scenario, and between $18-24/barrel in the low price case. Relative to the high oil price scenario, U.S. oil demand could increase by 1-1.5 million barrels per day and production could decrease by 1-2 MMBD given a sustained period of low oil prices (Table 4-6). By the mid-1990's, even with higher oil prices, the United States will need to import about 50% of its oil; imported oil is likely to supply over 60% of our requirements in the event of lower oil prices. U.S. oil imports could range between 8 and 11 MMBD, depending on oil prices, a significant increase from the current level of 5 MMBD (Figure 4-7). Our Allies in the OECD countries are expected to be even more dependent on imported oil, with requirements of between 13 and 16 MMBD by the mid-1990s (Figure 4-8). Imports from OPEC, particularly Persian Gulf producers, are expected to meet most of the growing demand in the non-Communist world. OPEC exports as a fraction of non-Communist world oil demand are likely to exceed 50% by the mid-1990s, approaching levels obtained in the 1970s, compared to their current share of 30% (Figure 4-9). OPEC's share of non-Communist world oil demand will undoubtedly be even higher if low oil prices persist.

Table 4-6

World Energy Outlook: High and Low Oil Price Scenario

	High Oil Price Scenario[a]			Low Oil Price Scenario[b]
	1990	1995	2000	1995
Oil Prices (1986 $/bbl)	20	26	33	15-20
U.S. Oil Demand (MMBD)	17.0	17.0	17.1	18-18.5
World Oil Demand (MMBD)	50.2	52.1	54.6	53-54
U.S. Domestic Oil Production[c] (MMBD)	9.4	8.0	7.2	6-7
U.S. Energy Demand (Quads)	83	89	94	88-91
% U.S. Imports	41	49	55	62-67
% World Oil Supplied by OPEC	46	52	56	62

Notes to Table 4-6:

[a] DOE, ''NEPP-VI Reference Case Projections," (draft), Jan 9, 1987.

[b] Composite Low Price case drawn from recent forecasts that included a Low Oil Price (See Appendix A, Table A-2).

[c] Includes crude oil and natural gas liquid production.

Major Uncertainties

Although recent forecasts share similar views on key trends in the world oil market -- declining U.S. crude oil production, growing dependence on Persian Gulf suppliers, and higher demand growth in LDCs -- they also emphasize the large uncertainties inherent in each of their scenarios. The key factor affecting demand is probably the level of world economic growth. For example, Rowen and Weyant estimate that world oil demand would be about ten percent higher by 1995 if the world's economy grew at rate of three percent as opposed to two percent.[20] Demand for oil will also be affected by *real* oil prices, which are influenced by exchange rate shifts between the dollar and other currencies. Huntington argues that oil demand in 1990 could be four million barrels per day higher in a hypothetical case in which the dollar depreciates in value against OECD currencies (i.e., OECD prices in dollars rise by 5% per year more than U.S. inflation) compared to a case in which exchange rate movements adjust for only differences in inflation rates between countries.[21] Huntington's study suggests that the recent depreciation in the value of the dollar might act as an additional stimulus to oil demand in OECD countries, because, in real terms, oil prices are declining faster in these countries than the U.S.

However, major oil-consuming countries might adopt policies that tend to dampen oil demand. For example, governments of the major oil-consuming countries may decide not to pass through lower oil prices to final users by either increasing taxes on petroleum products (e.g., Sweden, Denmark, Greece) or by not reducing controlled product prices by the full amount of the decline in crude oil prices (e.g., Portugal, Spain). In general, these policies will tend to dampen demand for oil, although at this time, the major oil-consuming countries (the U.S., Japan, and Germany) have not so far opted for this approach.

Government policies and actions increase uncertainty on the supply side as well. For example, governments in major oil-importing countries might decide, for national security reasons, to aid their domestic oil industry either by imposing taxes on imported oil or by providing tax benefits. Major producing nations will also attempt to intervene and manipulate the oil supply system. Key political issues that may affect the world oil market during the 1990s include:

- the ultimate outcome of the Iran-Iraq war and its impact on the political balance of power in the Middle East and within OPEC,
- the willingness of major swing producing countries (principally Persian Gulf nations) to expand output and ultimately productive capacity,
- and the amount of oil available for export from communist countries.

Finally, most forecasts explicitly acknowledge the possibility of a large-scale disruption in oil supply, which adds another element of uncertainty to the prevailing world energy outlook for the 1990s.

Notes to Chapter 4

1. Iraq was exempted from the quotas.
2. D. Wyss, "The Impact of Low Oil Prices on the U.S. Economy" Data Resources Inc., May 1986, p. 11 .
3. D. Wyss, "The Impact of Low Oil Prices on the U.S. Economy", p. 11.
4. Energy Information Administration (EIA), "The Impact of Lower World Oil Prices and Alternative Energy Tax Proposals on the U.S. Economy" (draft), April 1986, p. 15. These results are based on simulation results using the Data Resources Inc. (DRI) Quarterly Model of the U.S. economy.
5. National Petroleum Council, "An Interim Report on the U.S. Oil and Gas Outlook", October 1986, p. 2, 17-18; Energy Daily, "Offshore Rig Use Hits New Low", October 17, 1986, p. 3.
6. *Energy Daily*, "API Strikes Cassandra Pose", January 15, 1987.
7. Stripper wells produce less than 10 barrels per day. There are 450,000 of these wells in the U.S.; over 50% are located in Texas, Oklahoma, and Kansas.
8. Department of Energy, "Domestic and International Oil Situation", September 1986, p.8.
9. H.S. Rowen and J. P. Weyant, " The Oil Price Collapse and Growing American Vulnerability", (draft), 1986. We discuss longer-term trends affecting the supply/demand balance in a later section of this chapter.
10. D. Yergin, Cambridge Energy Research Associates, "Testimony presented to the Senate Finance Committee, Energy and Agricultural Taxation Sub-committee", Feb. 28, 1986.
11. EIA, "The Impact of Lower World Oil Prices and Alternative Energy Tax Proposals on the U.S. Economy" (draft), p. 5.
12. Department of Energy, Office of Policy, Planning and Analysis, "Low World Oil Prices Scenarios", May 1986. The OPPA study attempted to estimate demand for OPEC oil at each price, and then evaluated factors that would be necessary to sustain that price and production level (e.g., likelihood of OPEC production agreement, decline in non-OPEC production, rapid increase in demand).
13. EIA, "The Impact of Lower World Oil Prices and Alternative Energy Tax Proposals on the U.S. Economy" (draft), p. 5.
14. See Department of Energy (DOE/NEPP), "National Energy Policy Plan Projections to 2010 (final draft)", Washington DC, February 25, 1987; Energy Information Administration (EIA), "Annual Energy Outlook 1985," February 1986; Chevron Corporation, "World Energy Outlook", June 1986; Gas Research Institute (GRI), "1986 GRI Baseline Projection of U.S. Energy Supply and Demand, 1986; Ashland, "World Energy Outlook Through 2000", August 1986.
15. Chevron Corporation, "World Energy Outlook", p. 10.
16. See Cambridge Energy Research Associates and Arthur Anderson & Co., "The Future of Oil Prices: The Perils of Prophecy", 1984 for detailed discussion of each vintage oil price forecast as well key assumptions on supply and demand that went into each forecast.
17. Cambridge Energy Research Associates and Arthur Anderson & Co., "The Future of Oil Prices: The Perils of Prophecy", p. 15-16.

18. R. L Hirsch, ''Impending United States Energy Crisis'', *Science*, March 20, 1987.

19. Chevron Corporation, ''World Energy Outlook'', p. 2-7.

20. H.S. Rowen and J. P. Weyant, '' The Oil Price Collapse and Growing American Vulnerability'', (draft), 1986, p. 14.

21. H. G. Huntington, ''The US dollar and the world oil market'' *Energy Policy, 14:4*, August 1986, p. 299-306. The four MMBD difference represents a 6-7% effect.

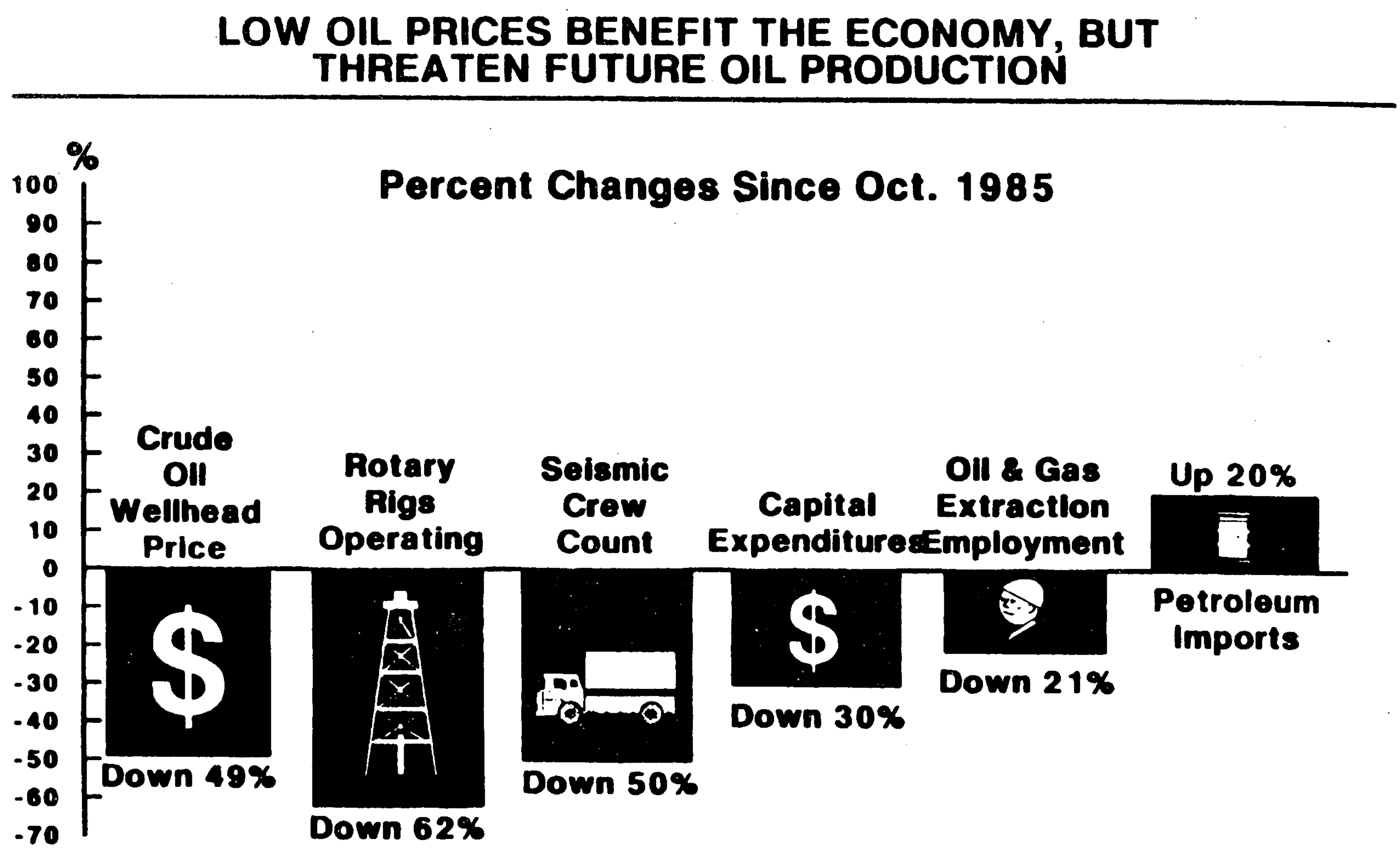


Figure 4-1. Low oil prices benefit the economy, but threaten future oil production.

Source: Department of Energy, "Domestic and International Oil Situation", September 1986.

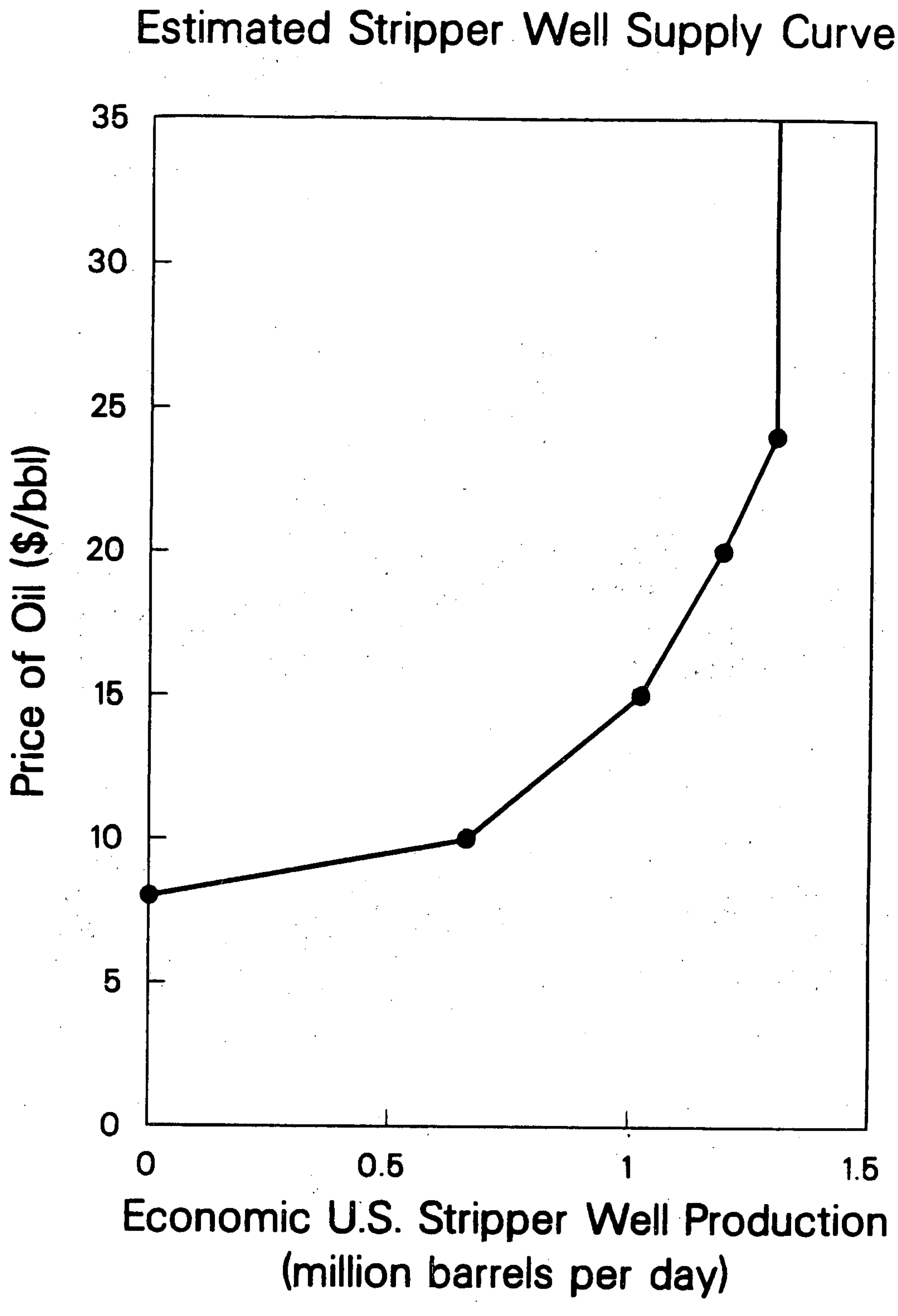


Figure 4-2. Estimated oil production from U.S. stripper wells at various oil prices. At oil prices of $15/barrel, about 300,000 barrels per day of production is uneconomic.

Source: Department of Energy, "Domestic and International Oil Situation", September 1986.

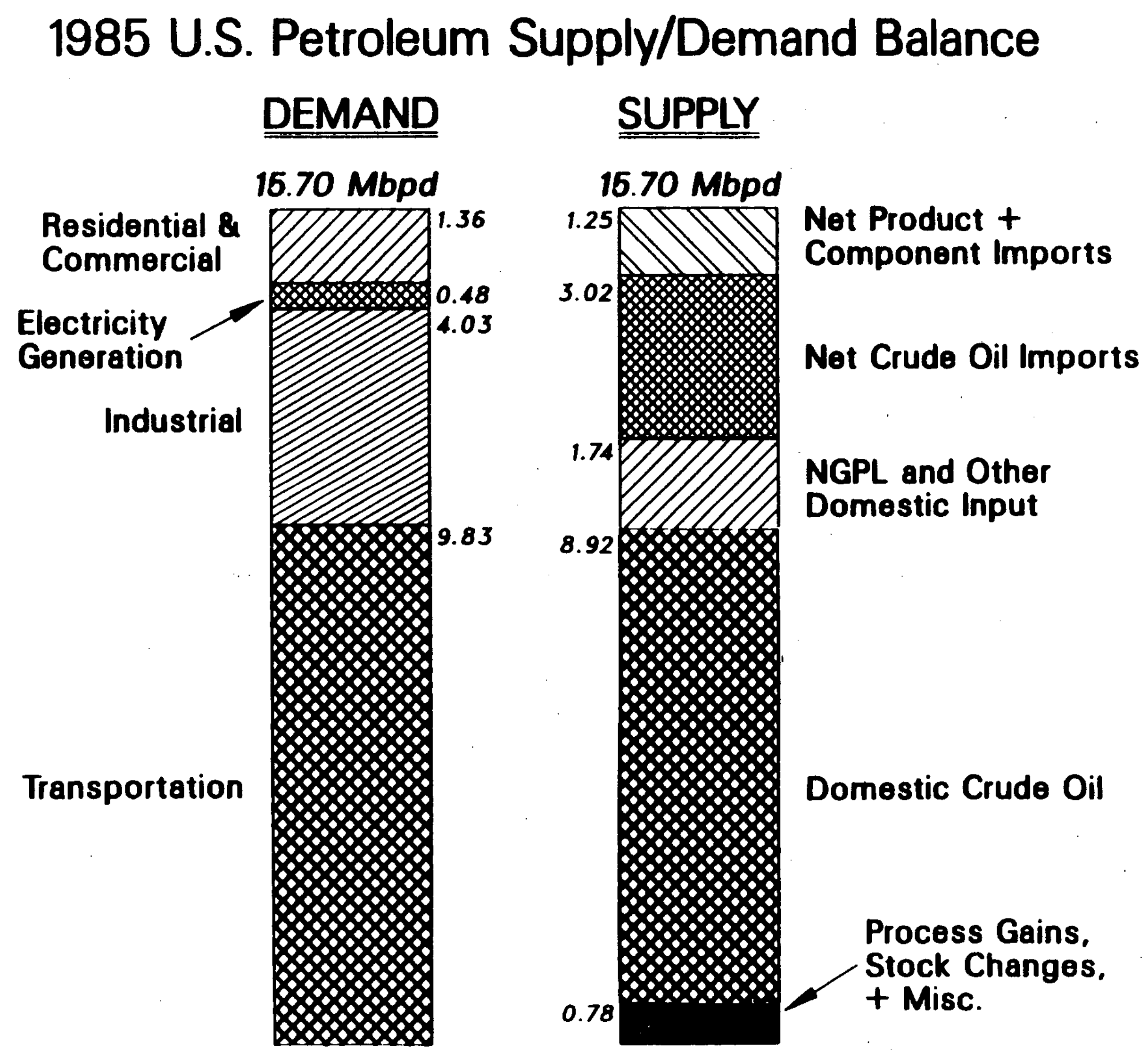


Figure 4-3. U.S. petroleum supply and demand in 1985.

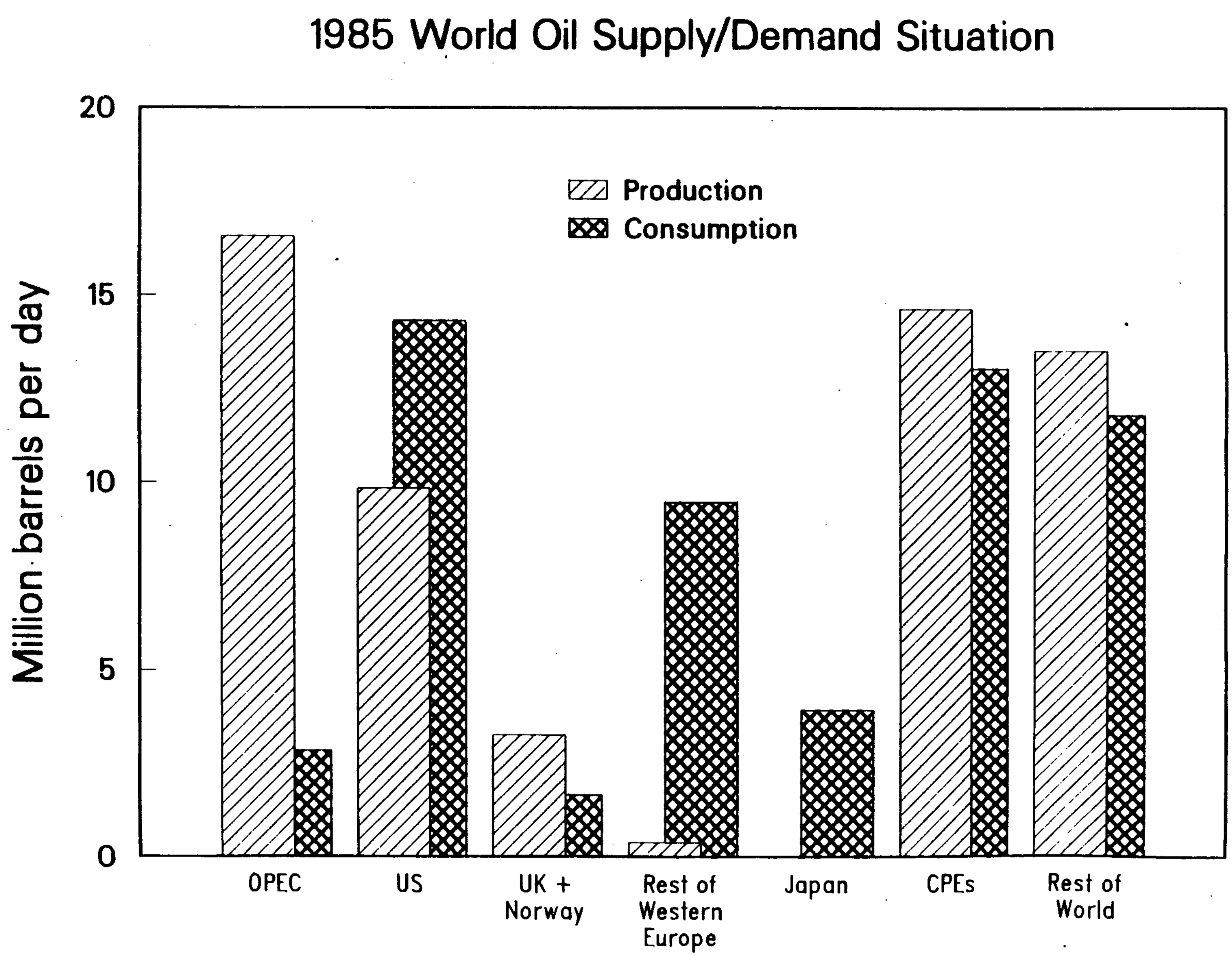


Figure 4-4. World oil supply and demand situation in 1985.

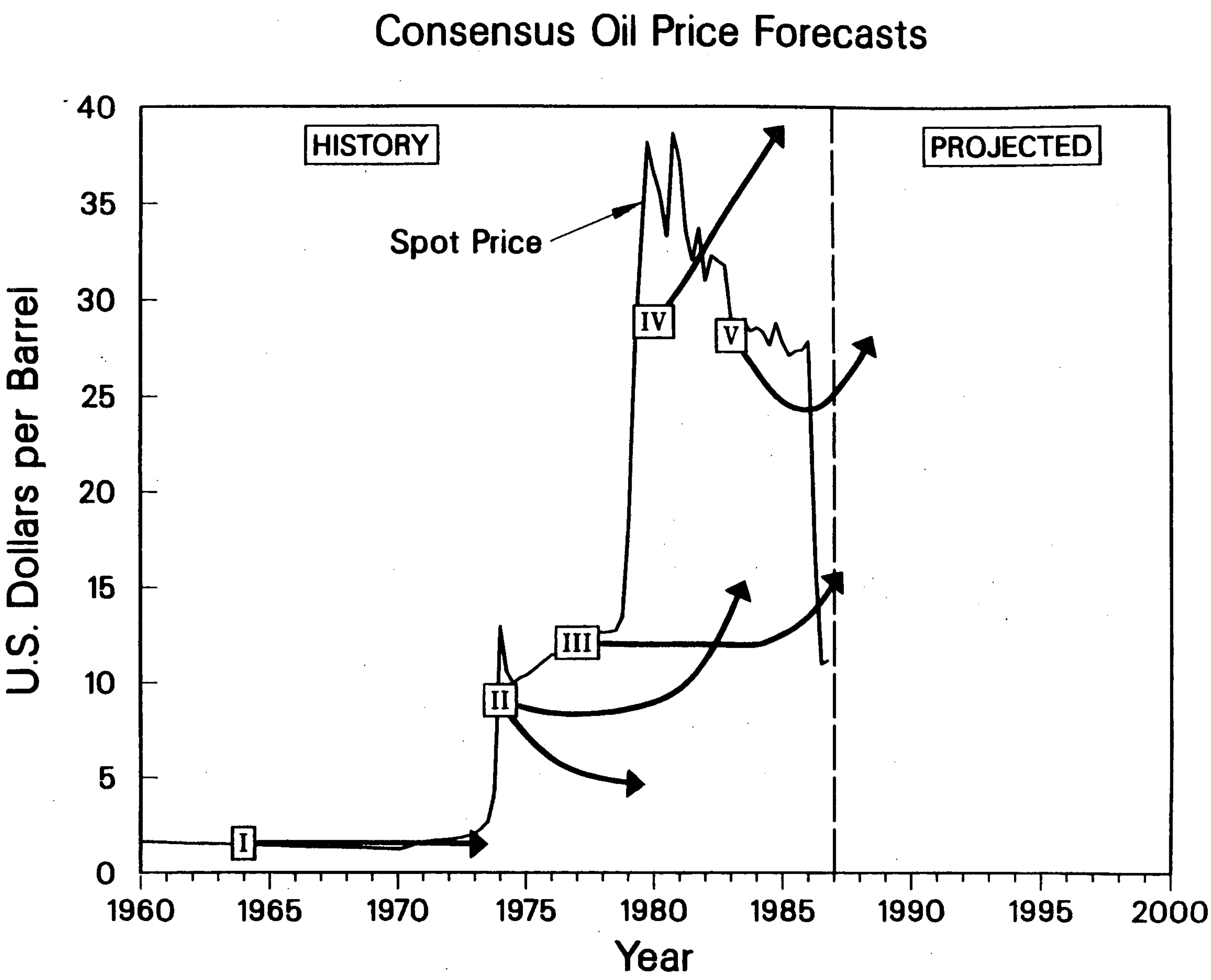


Figure 4-5. Consensus oil price forecasts and actual spot oil prices during the last 15 years. Forecasts are summarized into five periods (I through V); in vintage II, higher arrow represents European consensus forecasts while lower arrow reflects the North American consensus on future oil prices.

Source: Cambridge Energy Research Associates and Arthur Anderson & Co., "The Future of Oil Prices: The Perils of Prophecy", 1984.

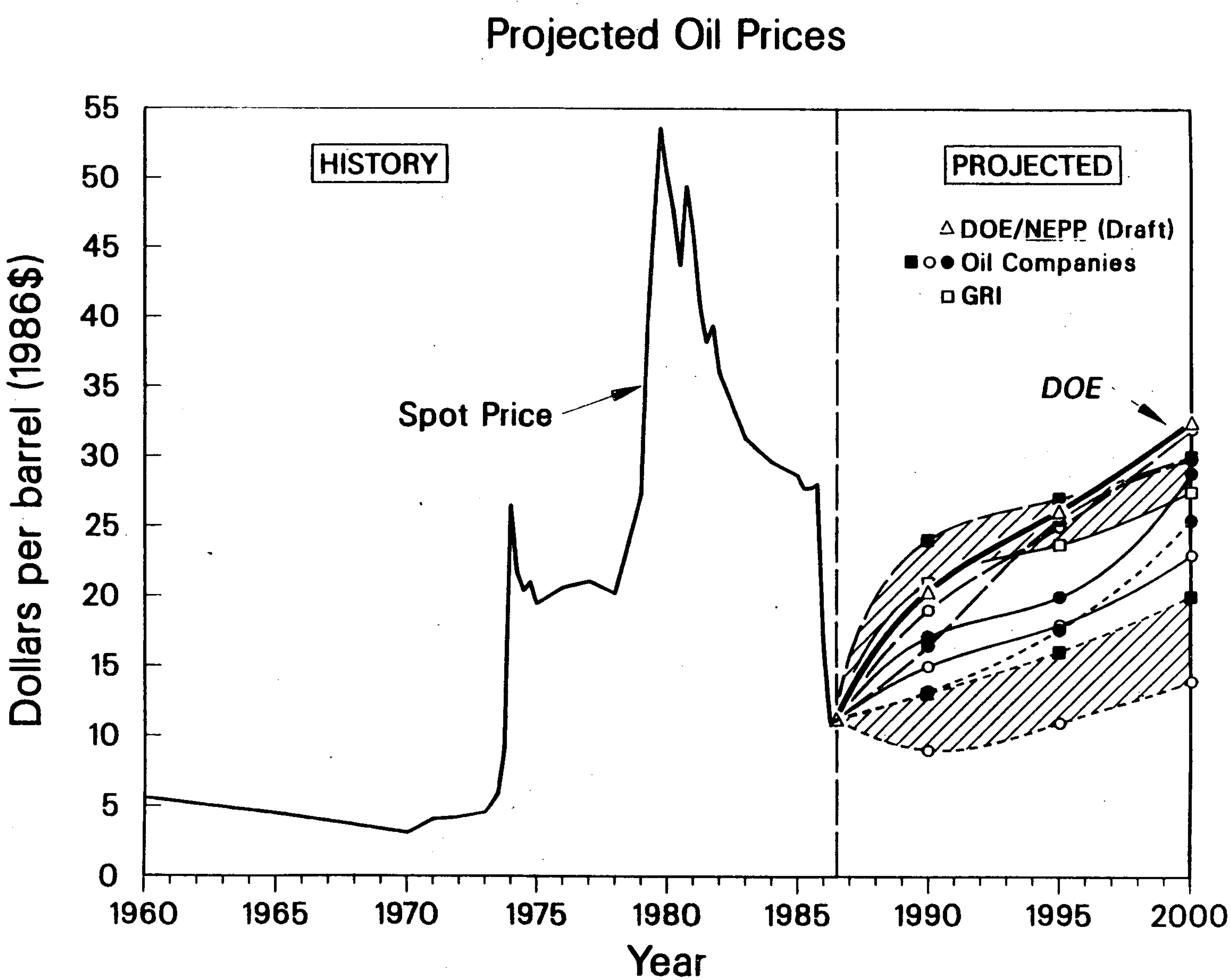


Figure 4-6. Current forecasts of future oil prices by various oil companies, industry groups, and government agencies. Shaded area shows range of higher and lower oil price paths.

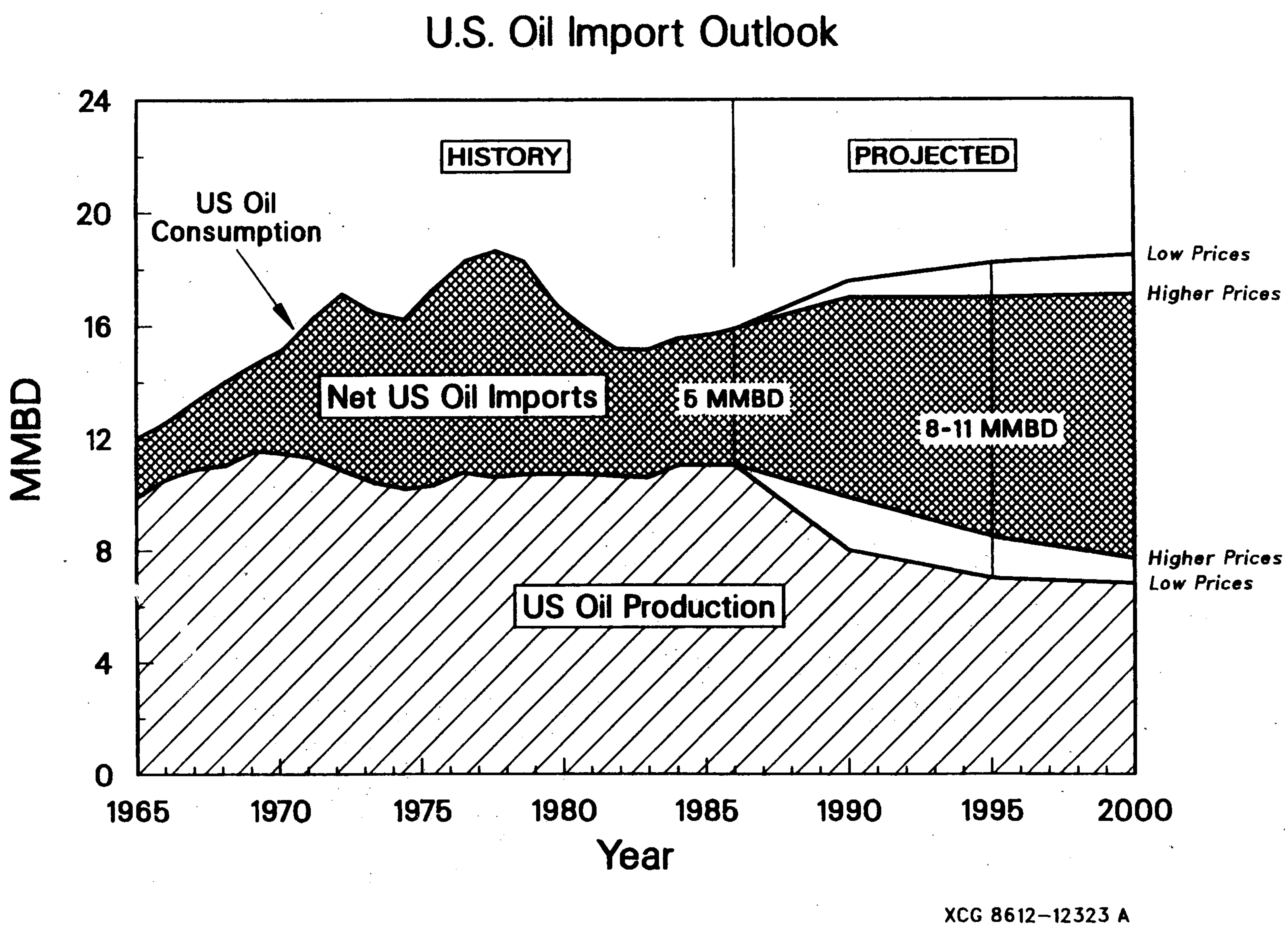


Figure 4-7. Projected level of U.S. oil imports during the 1990s under lower and higher oil price scenarios.

Source: DOE/NEPP (final draft); See Table 4-4 and Appendix A, Table A-2 for low oil price forecasts

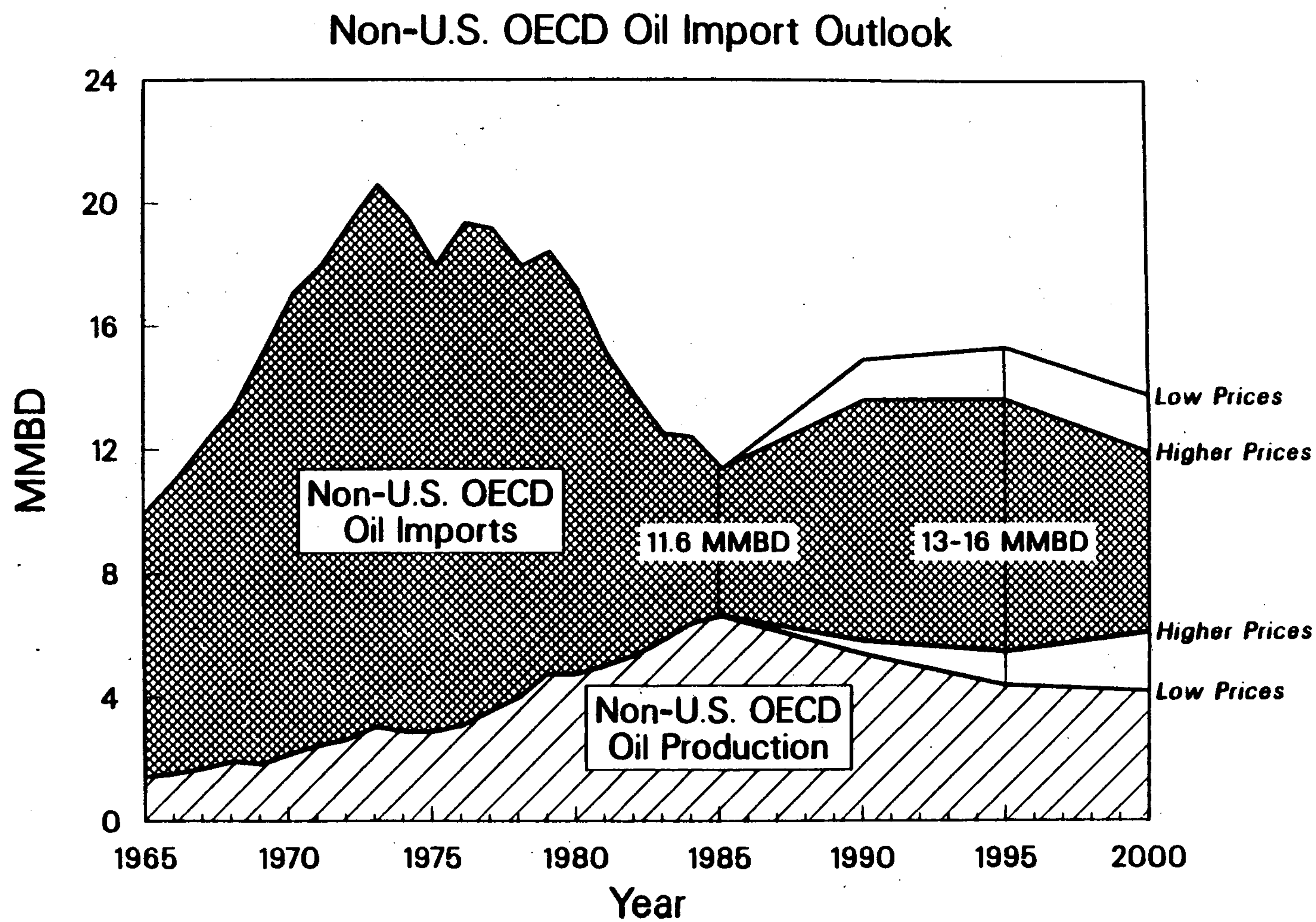


Figure 4-8. Projected level of non-U.S. OECD oil imports during the 1990s under lower and higher oil price scenarios.

Sources: DOE, "Domestic and International Oil Situation", September 1986; DOE/NEPP (final draft); See Table 4-5 and Appendix A, Table A-2 for low oil price forecasts

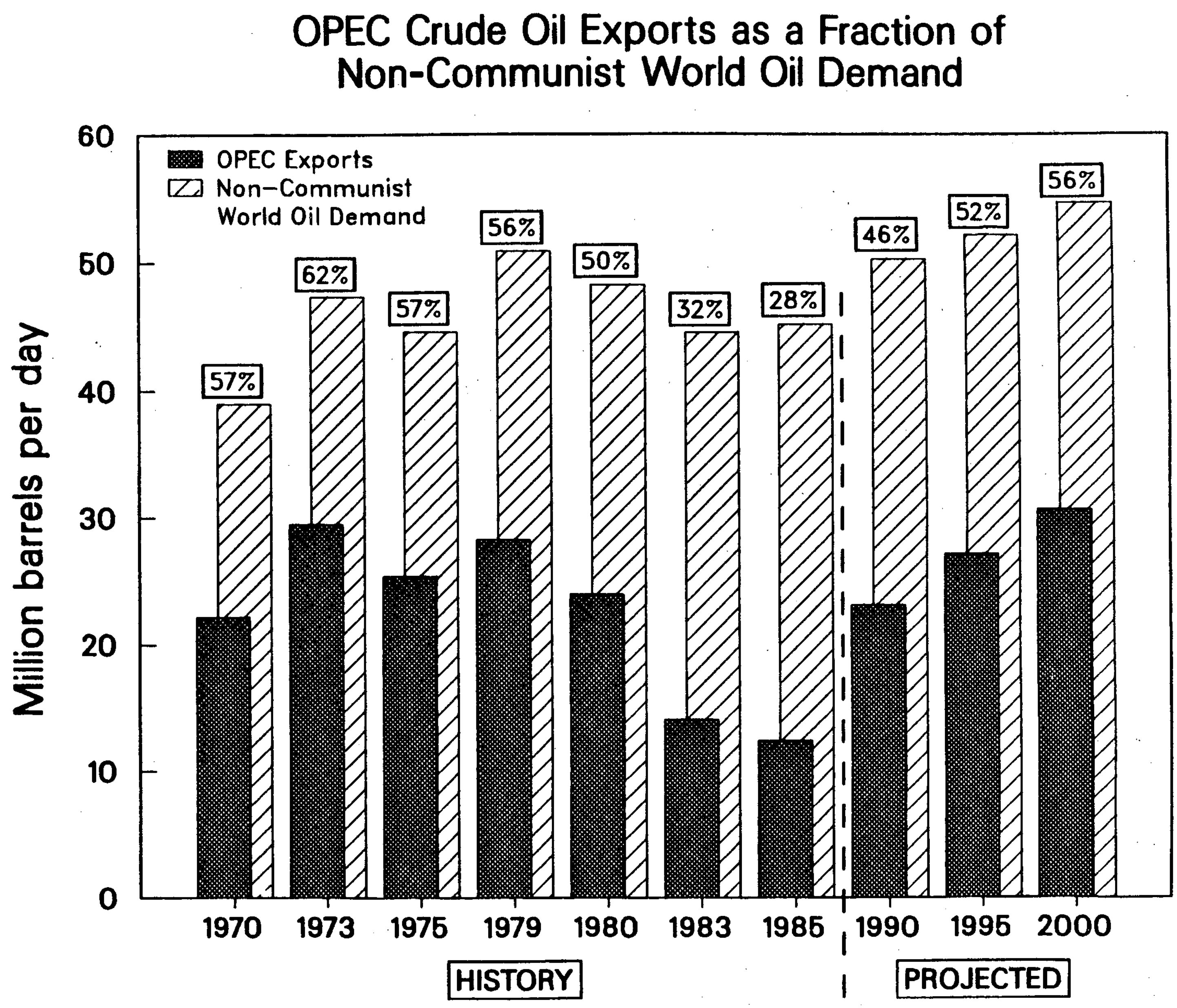


Figure 4-9. OPEC crude oil exports as a fraction of non-Communist world oil demand. Projections are based on DOE/NEPP base case forecast.

Chapter 5

OIL VULNERABILITY

Nature of U.S. Oil Vulnerability

The Importance of Oil

Oil has been described as the world's most important primary commodity. Commodities are characterized by uneven movements of supply and demand which are seldom in harmony with each other.[1] Thus, in the absence of a dominant regulatory presence (e.g., the Texas Railroad Commission or OPEC), oil prices could be expected to fluctuate widely based on the inherent nature of commodity markets. Oil is also one of the most flexible and portable sources of energy and plays a critical role in satisfying the energy requirements of every country and economy. Although oil's share of total consumption has declined since the 1970s, it is likely to remain the largest single energy source in the world into the 21st century. Oil still supplies about 40% of U.S. total energy consumption, and an even larger share for our Allies (e.g., Japan, 56%; OECD, 42%) [Figure 5-1]. Even if the U.S. were self-sufficient in oil production it would not solve the oil vulnerability problem as our Allies are tremendously dependent on imports and the U.S. economy would suffer if OECD nations could not receive adequate oil supplies. In the U.S., the transportation sector relies almost exclusively on oil (oil supplies 97% of energy consumed); moreover, it is not likely that transportation fuel substitutes will be available on a large scale during the next decade. Our Allies, especially Japan, and to a lesser extent, Western European nations, tend to rely more heavily on oil in the industrial sector.

An Integrated World Market

There is a tendency to think of U.S. oil vulnerability as simple and self-contained: the threat that oil supply from an insecure source will be cut off. Oil shortages, however, are largely defined by global, not local imbalances; their impact is worldwide. The cost of shipping oil half way around the world is only a small fraction of its delivered value even at today's lower prices. This means that, to a much greater extent than electricity or other fuels, oil is subject to a single worldwide market. In addition, the U.S. is obligated by treaty to share large oil shortages proportionally with the other oil-consuming nations in the International Energy Agency (IEA).

Effects of an Oil Shock

World oil shortages have major effects on oil prices; rapid increases in oil prices, in turn, cause major dislocations in the economies of oil-consuming countries. Economic losses from an oil price shock can be grouped into two general categories: 1) deterioration in the terms of trade of oil-importing nations as the price of imported oil rises relative to other prices in the economy, essentially purchasing power losses, and 2) reduction in potential output from temporary spurts in inflation and increased unemployment as the economy has difficulty adjusting to a sudden oil shock, essentially macroeconomic production losses. Economic analysis of previous oil price shocks suggests that one-half to two-thirds of total U.S. economic losses were attributable to macroeconomic consequences of the much higher oil prices.[2]

Oil demand is highly inelastic in a "short run" that can last for well over a year. Hence, small shortages can cause large price effects. The large oil price increases of 1973 and 1979-80 were caused by shortages of only a few percent of total world oil consumption. Conversely, between the third quarters of 1985 and 1986, the world oil price fell by 59% in dollars and by larger amounts in the currencies of other large oil-consuming countries, yet total world oil consumption increased by only 3.3% during this same period.

National Defense Requirements for Oil

It is worth noting that although the U.S. military requires oil, interruption of this oil supply is *not* the major source of concern in assessing U.S. oil vulnerability in the 1990s. Currently, direct military uses account for about 2-3% of U.S. total oil consumption. During a military conflict, oil requirements could be two to five times higher than during peacetime.[3] In addition, during wartime, indirect use of oil in the civilian sector to support military needs would have the next highest priority to military needs; yet, total military need for oil would be substantially less than the amount available from secure domestic production. The Defense Production Act ensures that national defense needs get priority and has been invoked only once since World War II (during the 1973 oil embargo for a brief period). The logistical problems of providing oil supplies where needed during a conflict are of greater concern than lack of oil. The principal effect of an oil supply disruption during mobilization would be economic (e.g., oil prices would be forced up) rather than military.

Concentration of Reserves and Production of the Persian Gulf

The Persian Gulf region occupies a critical position in analyzing U.S. oil vulnerability because a significant fraction of world oil production and reserves are concentrated in this relatively small and vulnerable region. The Persian Gulf accounts for almost 30% of the non-Communist world's current oil production, 45% of the world's internationally traded oil, and 56% of the world's reserves. Many of the governments in the region are politically unstable and the lengthy war between Iran and Iraq has further destabilized the region's geopolitical balance. In addition, the region's close proximity to the Soviet Union means that it is relatively easy for the Soviets to project a strong military presence; increased Soviet influence threatens Western security interests.

Oil transport routes out of the Gulf are also susceptible to disruption. The escalation of the Iran-Iraq War accompanied by threats/actions to close the Straits of Hormuz illustrates the relative ease with which Gulf nations can disrupt oil tanker transport from the region. Thus, the Persian Gulf stands out as an insecure oil source because of the combination of three factors - concentration of production and reserves, an exposed transportation system that is vulnerable to disruption amidst a region marked by political instability and wars.

Threats to the Oil Supply System

In this section, we review briefly the major threats to the world oil supply system, particularly to supplies from the Persian Gulf. Threats to supplies can be divided into threats to production and threats to transportation.

Threats to Oil Production

Among threats to oil production, civil and international wars are the most prominent. Revolutions and international wars can an interrupt oil supplies in several different ways. First, the hostilities themselves may interrupt supplies by destroying oil-producing facilities or making them too dangerous to use. The extent to which facilities are affected depends on the scope and intensity of the military actions, their proximity to the facilities, and the oil-producers' ability to work under wartime conditions. Military intervention by oil-consuming countries or the threat of it may play a key role in maintaining production. Oil production under wartime conditions is often surprisingly large; for example, production of Nigerian crude continued at a nearly normal rate during the Nigerian civil war. The current Iran-Iraq war has reduced but not eliminated oil production from those countries.

The outcomes of wars and revolutions can be important to oil production. For example, an isolationist victory in a revolution or some other triumph of ideology over economics can result in the withdrawal of a country from the world oil market. A war may also result in the unification of competitors for economic decision-making purposes, which would increase their monopoly power. This could be an outcome of the current Iran-Iraq war; a successful pan-Islamic movement could have devastating effects on world oil supplies.

Soviet domination of the Persian Gulf would pose a major threat to Western security interests. The Soviet threat should not be underestimated given their military strength and presence in the region (e.g., South Yemen, Iraq), their favorable geopolitical strategic location (i.e., border with Iran), and their competition with the major oil-consuming nations of the West. It is worth noting that, as an oil exporter, the Soviets tend to benefit from oil supply disruptions that lead to sharp increases in oil prices.[4] However, Soviet difficulties in Afganistan may be indicative of some limitations on their ability to project their power into the Islamic world.

We have already mentioned the effect that wars could have on the monopolization of oil. Monopolies that threaten energy security can also occur without any war or other military activity. We will discuss below the disruption potential index of OPEC and of the Persian Gulf, which, even at present, is large enough that if the oil producers of the gulf chose to act as a single force for any length of time, they could drive the world oil market into deficit and force oil prices up drastically while still producing substantial amounts of oil. Any political development that could lead to a unified Persian Gulf monopoly would be a serious threat to U.S. energy security.

Both natural disasters and terrorist attacks can interrupt oil production. Neither is as large a threat as war, Soviet domination of the Persian Gulf, or a united Persian Gulf monopoly.

Threats to Oil Transportation

The Straits of Hormuz at the entrance to the Persian Gulf are the single most vulnerable point in the world's oil transportation system. Currently, about seven million barrels per day are moved by tankers through these straits, down from a peak of 14-16 MMBD during the late 1970s (Figure 5-2). Much of this decline is the result of decreasing oil production in the Persian Gulf.

However, that trend is likely to be reversed during the next decade. More important, at least from the standpoint of assessing vulnerability of oil transport lines, is the fact that several Persian Gulf nations (principally Iraq and Saudi Arabia) have constructed pipelines that bypass the Straits of Hormuz to reach tanker ports outside the Persian Gulf. For example, the Iraq-Turkey pipeline runs from Iraq through Turkey to the Eastern Mediterranean, and carried over 1.5 MMBD in 1985. Moreover, Iraq is expanding existing lines and is in the process of constructing additional pipelines. The Saudis have built a pipeline that carries about 1.5 MMBD to the Red Sea port of Yanbu, and they are in the process of increasing its capacity. These alternative delivery routes effectively reduce the size of a supply disruption that could be caused by a blockage of the Straits of Hormuz.

Changes in U.S. Oil Vulnerability

The principal issues to consider in assessing possible changes in oil system vulnerability between now and the 1990s include: 1) increased reliance upon OPEC oil, 2) increased concentration of production in the Persian Gulf, 3) decreases in spare production capacity, 4) greater dependence of the U.S., OECD nations and non-OPEC LDCs on imported oil from insecure supply areas, 5) the likelihood, size, and duration of potential oil supply disruptions, and 6) ability to minimize the effects of disruptions.

Concentration of Oil Production in the Persian Gulf

The fraction of the world's oil production that comes from OPEC countries, the Middle East, and especially the Persian Gulf will increase significantly during the 1990s. Such a shift is almost inevitable because of increased requirements for imported oil (see Chapter 4) and because most oil reserves and surplus production capacity are in the Persian Gulf. About 66 percent of the world's proved oil reserves that are economically recoverable with current technology are controlled by OPEC countries, and over 55 percent are located in the Persian Gulf (Figure 5-3). Comparing a country's or region's share of world oil reserves to its share of current production highlights this trend (Table 5-1). For example, the ratio for the United States is under 0.3, which suggests that the level of U.S. oil reserves relative to our current production rate is less than 30% of the world average. This ratio increases to 0.5 if the U.S., Canada, and Mexico are considered together. On the other hand, OPEC's reserves are about twice the world average; the ratio of reserves to production rate for Kuwait, Saudi Arabia and their shared Neutral Zone is more than three times the world average. In the absence of major new discoveries, production will tend inevitably to shift from regions with low ratios to areas with high ratios. Moreover, since oil exploration expenditures are decreasing, major new discoveries in secure regions are unlikely.

Table 5-1

Likely Sources of Future Oil Production

	Percent of World Oil		
Area	1985 Production	Reserves 12/31/85	Ratio
U.S.	16.0%	4.1%	0.3
U.S., Canada & Mexico	24.0%	12.0%	0.5
All OPEC	33.1%	66.5%	2.0
Middle East	22.0%	56.8%	2.6
Persian Gulf	21.0%	56.0%	2.7
Saudi Arabia, Kuwait & Neutral Zone	11.2%	37.7%	3.4
Saudi Arabia	8.4%	24.5%	2.9

Source: EIA, *International Energy Annual, 1985*, Oct. 1986; Arthur Anderson & Co. & CERA

Reduction in Spare Capacity

In the absence of new investment, oil production capacity in high cost regions of the world can be expected to decline at roughly 5% to 10% per year as wells exhaust their reservoirs and equipment wears out. Thus, some new investment would be required just on the basis of steady or slowly increasing projected demand. Outside of OPEC and countries tacitly cooperating with OPEC's production restrictions, such investment will not normally produce spare capacity. Once capital has been invested in oil production capacity, it is normally economic to use that capacity fully in order to produce oil with it as rapidly as possible.

For OPEC nations (and those countries that tacitly cooperate), the situation is somewhat different. Production restrictions imply that existing capacity is not being fully utilized; hence, investment in additional capacity cannot easily be justified. There are two possible cases, neither of them very likely, in which OPEC might consider expanding its production capacity. First, some additional capacity might be justified on the basis of providing for seasonal peaks in demand, so that the need for inventories would be reduced. However, crude oil demand is only mildly seasonal, and oil can be inventoried at moderate expense. Second, to the extent that future OPEC production quotas are determined based on unused capacity, there may be an incentive to increase capacity in order to gain an increased quota. However, OPEC quota-setting is a highly political process influenced by many factors other than spare capacity. Furthermore, spare capacity is not easily verified and it is not in OPEC's interest to reward large increases in capacity with quota increases. Hence, unlike the Texas Railroad Commission's past setting of production quotas as a fraction of installed capacity (''proration''), installation of additional oil production capacity in the face of existing spare capacity is unlikely to result in a significant increase in oil production.

The situation is somewhat different for the two OPEC nations that are directly involved in the region's major military conflict, Iran and Iraq. The war has resulted in a decrease in usable capacity in each country. After the war, capacity will likely be restored to near prewar levels. Thus, with this exception, it is reasonable to expect that spare capacity in OPEC will not increase unless oil demand is significantly lower than is generally anticipated.[5]

Increases in demand for OPEC oil will tend to lead to reductions in spare capacity. A decrease in spare capacity would increase both the market power of oil producers and the vulnerability of oil consumers.

Disruption Indices

One measure of vulnerability is the extent to which intentional actions, or the incidental effects of political events, or a natural disaster in a region can mean that oil demand at existing prices cannot be met. Such a disruption would have a major effect on the spot price of oil. We should also point out that disruption potentials are related to monopolization potentials. If any single supplier or unified group of suppliers has the power to produce such a disruption while still producing some oil, their temptation to do so or to threaten to do so is great.

We developed two quantitative indicators to illustrate the potential effects of a major supply disruption in particular regions: the disruption potential index (DPI) and the disruption depth index (DDI). The disruption potential index (DPI) is the ratio of one country's or area's oil production divided by the spare production capacity that exists *elsewhere* in the world.[6] In other words, it is a measure of how much oil a country produces that could not be replaced by production in other countries if it disappeared from the market. This is a "short-term" disruption potential, but in the slowly changing world of oil market fundamentals, the short term is measured in years, not months. Values greater than one mean that the country or area has the potential, by itself, to throw the world oil balance into an unavoidable deficit. Values that substantially exceed one indicate that the country or area has the potential to create a severe oil supply deficit while maintaining substantial production at the resulting much higher prices.

The disruption potential index is an indicator of the ability of a country or region to bring the world oil market to the point of disruption; it does not measure the seriousness of that disruption. Thus, by definition, every oil exporter's disruption potential becomes large as the rest of the world's spare capacity becomes small. The disruption depth index (DDI) is an alternative way of looking at disruption potential that emphasizes the *severity* of a potential disruption (see Table 5-2 for formulas and relationship of indices). In calculating the DDI, we subtract spare capacity elsewhere from a country's production and then divide the difference by the free world's total consumption.[7] The disruption potential index is more useful for thinking about the incentives of a producing country or area, while the disruption depth index helps to assess the potential damage to the world oil market caused by loss of that country or area. The DDI is negative if the DPI is less than one, and positive if it is greater than one. If the DDI is positive, its magnitude measures the fraction of the world's oil consumption that would be lost if that country's production and spare capacity were lost, assuming use of the remainder of the world's spare capacity.

Table 5-2.	
Formulas for Disruption Indices	
Notation	
OP_i	= Oil Production in area i
SCE_i	= Spare oil production Capacity Elsewhere than area i
FWC	= Free World oil Consumption
TWC	= Total World oil Consumption
DPI_i	= Disruption Potential Index of area i
DDI_i	= Free world Disruption Depth Index of area i
$TDDI_i$	= Total world Disruption Depth Index of area i
Definition of Indices	
DPI_i	$\equiv OP_i \div SCE_i$
DDI_i	$\equiv (OP_i - SCE_i) \div FWC$
$TDDI_i$	$\equiv (OP_i - SCE_i) \div TWC$
Relationship of Indices	
DPI_i	$= 1 + DDI_i \cdot FWC \div SCE_i$

It is important to note that the assumed spare capacities in Table 5-3 do not include release capacity of government-controlled strategic petroleum reserves. We will discuss the mitigating effects of consumer nation public stockpiles on potential supply disruptions later in this chapter.

Interpreting the Disruption Indices

Currently, the disruption potential indexes for Saudi Arabia and for Iran/Iraq are under one (Figure 5-4 and Table 5-3).[8] This suggests that, at present, there is no single OPEC country that can put the world oil market into deficit. The DPI for the entire Persian Gulf is 3.8, and the Disruption Depth Index is 0.18. This means that a loss of about 26 percent[9] of Persian Gulf production would necessarily throw the world oil balance into deficit, and that a loss of all of it would deprive the free world of at least 18% of its oil supply. OPEC's disruption potential index of 38 is primae facie evidence that OPEC is not unified and interested in maximizing its profits in the short-to-medium term. If the cartel acted as a unified producer, OPEC could decide to cut its production by just over 2.5% and throw the world market into deficit.

Table 5-3
Disruption Indices

Current Situation: 8.5 MBD Spare Capacity[a]

	(A) Capacity[b]	(B) Oil Production	(C) Own Spare Capacity[c]	(D) Other's Spare Capacity[d]	(E) Disruption Potential Index[e]	(F) B-D	(G) Disruption Depth Index[f]
Saudi Arabia	8.1	4.5	3.6	4.9	**0.92**	-0.4	**-.01**
Iran, Iraq	4.95	3.6	1.35	7.15	**0.50**	-3.6	**-.08**
Persian Gulf	16.75	11.2	5.55	2.95	**3.8**	7.4	**.16**
OPEC	25.69	17.65	8.04	0.46	**38**	17.2	**.38**

[a] We assume that 95 percent of spare capacity is in OPEC; total spare capacity is 8.04/0.95 = 8.46

[b] Installed capacity estimates are from Arthur Anderson and Associates and Cambridge Energy Research and Associates, *World Oil Trends: A Statistical Profile*, 1986.

[c] Col C = A - B

[d] Col D = 8.5 MBD - C

[e] Col E = B ÷ D

[f] Col G = F ÷ 45.7 MBD

Hypothetical time in 1990's: 4.5 MBD Spare Capacity

	(A) Capacity	(B) Oil Production[h]	(C) Own Spare Capacity	(D) Other's Spare Capacity	(E) Disruption Potential Index[i]	(F) B-D	(G) Disruption Depth Index[j]
Saudi Arabia	8.5	6.5	2.0	2.5	**2.6**	4.0	**.08**
Iran, Iraq	7.3[g]	5.7	1.6	2.9	**2.0**	2.8	**.05**
Persian Gulf	19.5	16.4	3.1	1.4	**11.7**	15.0	**.29**
OPEC	28.4	24.1	4.3	0.2	**120**	23.9	**.46**

[g] Assume Iran-Iraq war ends; but capacity not quite at pre-war levels (7.7 MBD).

[h] Gas Research Institute, *Baseline Projection of U.S. Energy Supply and Demand: 1995 data*. 1986.

[i] Col D = 4.5 MBD - C

[j] Col G = F ÷ 52.1 MBD

We then estimated disruption potential ratios for a hypothetical situation in the 1990s. We assume that world spare oil production capacity will decrease by 50%, from 9 to 4.5 MMBD. OPEC production is projected to reach 24.1 MMBD, as world production shifts toward uncommitted Persian Gulf reserves. We assume that the Iran-Iraq war ends, and both countries increase their productive capacity (but not quite to prewar levels) and production. The effect of these changes on the Disruption Potential Index would be dramatic. For example, the disruption potential index for Saudi Arabia increases to 2.6 under this hypothetical scenario for the mid-1990s. This means that a Saudi decision to cutback production by about 40 percent would throw the world oil market into deficit. This level of supply disruption is not implausible and could occur if the country experienced severe internal strife or if an unfriendly regime decided to act as a lone monopolist. We also calculated the disruption potential index under a hypothetical situation in which Iran and Iraq acted as a single decisionmaker. The DPI for both countries was 2.0 and this scenario reflects the possibility and implications of victory by one side in the war. This analysis illustrates the increased influence of Iran and Iraq in the world oil market if their production was controlled by one decisionmaker. Compared to the current situation, the disruption potential indices for the Persian Gulf region and for all of OPEC would triple in our hypothetical 1990s case. The disruption depth indices would increase as well. For example, the loss of all production from Saudi Arabia would create an eight percent deficit for the non-Communist world, while loss of the entire Persian Gulf would create a 29 percent deficit.

The Role of Inventories

In this section, we discuss oil importing countries' strategic inventories, such as the U.S. Strategic Petroleum Reserve. The discussion includes a brief summary of the history of such reserves, analysis of the interaction of strategic reserves and private inventories, as well as growth projections for reserves. We then treat strategic reserves as temporary spare capacity and analyze their impact on our indicators of vulnerability.

History and Projection

In response to the oil price shock of 1973, the U.S. decided to build a strategic petroleum reserve. The reserve's target was 750 million barrels, a level that corresponded to approximately 100 days of U.S. oil imports during the late 1970s. The reserve currently has more than 520 million barrels and is being filled at the rate of about 0.035 MMBD.[10] Other oil consuming countries are also building strategic oil inventories, although their total reserves are not as large as those of the United States. Figure 5-5 shows the buildup of government-held oil inventories for North America and for all of the OECD. By 1986, oil inventories held by OECD governments exceeded 20 days of total OECD consumption.

In order for government-held strategic inventories to be effective, they must be a supplement to privately-held inventories. Therefore, it is instructive to examine total inventories as well as government-held inventories (see Figure 5-6). During the early years of government inventory build up (except for 1979, the year the Iran-Iraq war started), private inventories also increased. Between 1983 and 1986, however, private inventories decreased more than government inventories increased, so the total level of inventories fell. It is incorrect to conclude that private strategic reserves were reduced in response to the increased public reserves, because private inventory levels are affected by two other key factors.

First, private inventory levels are sensitive to price expectations, increasing during periods when industry expects oil prices to increase and decreasing when industry expects oil prices to decrease. During the late 1970s, the oil industry expected prices to be at least stable; from 1983 until the price collapse in 1986, the industry projected declining oil prices (moderately) in the near term.[11] This explains much of the change in private inventories.[12]

Second, the relatively high oil prices of the early 1980s helped account for the reduction of private inventories. In setting inventory levels, oil companies must, to some extent, trade off the convenience, supply reliability, and operating cost savings allowed by more generous operating inventories against the higher costs of holding those inventories. The higher price of oil and, in the U.S., the higher real interest rates of the early 1980s influenced companies to keep smaller inventories.

It is generally accepted that public oil stockpiles can mitigate the effects of a supply disruption. In assessing the value of strategic reserves it is worth noting that the release rate is probably the key indicator (actually the limiting factor) for large oil supply shortages of short duration (i.e., the higher the feasible release rate, the more valuable a given amount of inventory). Conversely, if a crisis creates only a small shortage of available oil, a low release rate will be adequate. However, in the event of a lengthy oil supply disruption, the total stock of public inventories will be the limiting factor on the reserve's value.

Currently, oil can be released from the U.S. Strategic Petroleum Reserve at 2.3 MMBD for 120 days and at declining rates thereafter. The entire reserve can be emptied in a year, at an average supply rate of 1.4 MMBD. The initial release rate for OECD strategic inventories as a whole is over 3 MMBD. The OECD currently could release an average of about 2.1 MMBD for a whole year.

Release of strategic inventories in a crisis is not automatic. It requires governmental decisions (by the President in the U.S.) and is likely to involve international coordination. Although it is the stated policy of the U.S. government to release strategic reserves promptly and rapidly in a crisis, delays in making the required governmental decisions, and even failure to obtain them are certainly possible. The possibility of instituting automatic release of inventory in a crisis by selling short-term options to buy oil from the reserve at high prices has been considered and rejected in the U.S.

Inventories as Temporary Spare Capacity

Until they are exhausted, public stockpiles can act like spare capacity during a crisis. It is instructive to explore the effect of inventories on the disruption indices defined above under this assumption. First, we reexamine the current situation, assuming that inventories in IEA countries can produce the equivalent of 2 MMBD of spare capacity over the duration of a "short-run" disruption (see Table 5-4). Disruption potential indices (DPI) decrease substantially. The index for Saudi Arabia drops from 0.92 to 0.65, while the DPI for Iran and Iraq decreases from 0.50 to 0.39. The DPI for the entire Persian Gulf and all of OPEC drop by 40 to 80 percent respectively. The disruption depth indices for all four sources of production are decreased by 0.04 each.

Table 5-4 also show the results for our hypothetical scenario of the mid-1990s along with the additional assumption that IEA inventories contribute the equivalent of 3 MMBD of secure spare capacity during a disruption. The disruption potential index (DPI) decreases sharply for each country and region. For example, the DPI falls from 2.6 to 1.2 for Saudi Arabia compared to the situation without use of strategic reserves. The DPI drops from 11.7 to 3.7 for the Persian Gulf nations. The effect on the disruption depth index is substantial, but not as dramatic. For each of these sources, it decreases almost 0.06.

Table 5-4
Disruption Indices with Strategic Inventories

Current Situation: 8.5 MBPD Spare Capacity Plus 2 MBPD from Inventories[a]

	(A) Capacity[b]	(B) Oil Production	(C) Own Spare Capacity[c]	(D) Other's Spare Capacity[d]	(E) Disruption Potential Index[e]	(F) B-D	(G) Disruption Depth Index[f]
Saudi Arabia	8.1	4.5	3.6	6.9	.65	-2.4	-.05
Iran, Iraq	4.95	3.6	1.35	9.15	.39	-5.6	-.12
Persian Gulf	16.75	11.2	5.55	4.95	2.3	6.3	.14
OPEC	25.69	17.65	8.04	2.46	7.2	15.2	.33

[a] We assume that 95 percent of spare capacity is in OPEC; total spare capacity is 8.04/0.95 = 8.46

[b] Installed capacity estimates are from Arthur Anderson and Associates and Cambridge Energy Research and Associates, *World Oil Trends: A Statistical Profile*, 1986.

[c] Col C = A - B

[d] Col D = 8.5 MBD - C

[e] Col E = B + D

[f] Col G = F + 45.7 MBD

Hypothetical time in 1990's: 4.5 MBPD Spare Capacity plus 3 MBPD from Inventories[g]

	(A) Capacity	(B) Oil Production[h]	(C) Own Spare Capacity	(D) Other's Spare Capacity	(E) Disruption Potential Index[i]	(F) B-D	(G) Disruption Depth Index[j]
Saudi Arabia	8.5	6.5	2.0	5.5	1.2	1.0	.02
Iran, Iraq	7.3[1]	5.7	1.6	5.9	.97	-.2	-.004
Persian Gulf	19.5	16.4	3.1	4.4	3.7	12.0	.23
OPEC	28.4	24.1	4.3	3.2	7.5	20.9	.40

[g] Assume Iran-Iraq war ends; but capacity not quite at pre-war levels (7.7 MBD).

[h] Gas Research Institute, *Baseline Projection of U.S. Energy Supply and Demand: 1995 data.* 1986.

[i] Col D = 4.5 MBD - C

[j] Col G = F + 52.1 MBD

Changes in U.S. Oil Import Patterns

As discussed in Chapter 4, U.S. oil imports are projected to increase from the current level of 5.2 MMBD to 8-11 MMBD during the mid-1990s. In 1985, almost 40% of the oil imported by the United States was supplied by four LDCs (Indonesia, Mexico, Nigeria, and Venezuela), while Canada and the United Kingdom supplied about 20%. Beginning in 1977, total U.S. oil imports began to decline though imports from these six countries remained stable. Thus, by 1982, an ever-increasing share of imported oil was supplied from secure sources in OECD and non-Middle Eastern developing countries (Figure 5-7).

However, this trend is likely to be reversed during the next decade for several reasons. First, most forecasts predict that North Sea oil production will begin to decline by the early 1990s, with sharper decreases projected for the United Kingdom. The amount of oil available from the U.K. and Canada will also be limited by a price-induced slowdown in the development of high-cost reserves. In addition, LBL's International Energy Studies Group (LBL/IES) projects that rising domestic demand in Indonesia, Mexico, Nigeria, and Venezuela will cause these countries to limit their exports (Figure 5-8). Domestic demand in these four countries is projected to double from current levels by the year 2000 (i.e., 2.2 MMBD to 4.4 MMBD). During this period, oil production is projected to increase by about 2.5 MMBD in these countries. However, LBL/IES predicts that growth in demand for oil in the rest of the world and increased exports from these countries to meet that demand could mean that the amount of oil available for export to the U.S. decreases by about 10 percent, from 2.0 MMBD to 1.8 MMBD (See Appendix B). As a result of this decrease, the U.S. would again become more dependent on imported oil from Persian Gulf countries.

Conclusion

In this section, we summarize our assessment of U.S. vulnerability to oil supply interruptions in the 1990s, including a discussion of the principal uncertainties that affect this assessment.

The Assessment

Overall, we conclude that U.S. oil vulnerability is increasing. Lower oil prices exacerbate our vulnerability to a supply disruption, while the availability and use of strategic petroleum reserves can substantially mitigate the effects of an oil supply disruption. In our view, a recent study by Henry Rowen and John Weyant provides the most convincing quantative evidence on the growing U.S. oil vulnerability during the 1990s.[13] Rowen and Weyant estimate costs to the U.S. economy of year-long oil supply interruptions of various sizes (half and full Persian Gulf disruption) under two different price scenarios and the basecase assumption that government-held strategic reserves are not released (see Figure 5-9). Estimates of economic losses are based on median results from the Stanford Energy Modeling Forum's study on macroeconomic impacts of energy shocks. We offer the following observations on their results:

- It is important to note that the scenarios considered by Rowen and Weyant are larger than any actual disruptions that have occurred, although they are internally consistent and plausible for use in a vulnerability assessment. In our opinion, the economic losses associated with the "Half Persian Gulf Disruption" are probably the best available single indicator of relative U.S. oil vulnerability if strategic reserves are thought of as a strategy for responding to disruptions, rather than as a method for reducing vulnerability.

- In this situation, potential U.S. economic losses from very plausible Persian Gulf disturbances are substantial (i.e., four to six percent of U.S. GNP by the mid-1990s for the high and low oil price scenarios, respectively).
- Vulnerability increases during the mid-1990s irrespective of oil price scenario, although lower oil prices lead to greater U.S. vulnerability, particularly after 1995.

Rowen and Weyant also analyzed economic losses that would occur in the $15/barrel oil price scenario assuming that a crisis is met by a year-long 3 MMBD release of government-held strategic petroleum reserves (see Figure 5-10). Use of strategic reserves reduces economic losses by almost a factor of two (e.g., from six to about three percent of U.S. GNP in 1995), although the dollar magnitude of losses are still enormous. Not surprisingly, we also observe that use of strategic reserves seems to produce a relatively fixed reduction in the level of economic losses rather than reductions that are proportional to the size of the disruption. One qualification to keep in mind: this figure shows the effect of strategic reserves at their best. In a sense, a one-year disruption is their design target. On a relative basis, release of strategic reserves would be somewhat less effective against a shorter but larger disruption or against a longer one.

The Uncertainties

An assessment of oil vulnerability would be incomplete without a discussion of the key uncertainties inherent in such an analysis. Obviously, it is not possible to predict geopolitical events and their effects, although it is a reasonable assumption that the Persian Gulf region will continue to suffer from political instability. The situation in the Gulf is quite unsettled - the outcome of the Iran-Iraq war is in doubt and a consensus does not exist on the ramifications of various possible outcomes of the current conflict. In addition to a major regional war, the Middle East and Persian Gulf are susceptible to political/cultural movements such as pan-Islamic fundamentalism or internal revolution in a major oil-producing country. Secondary geopolitical concerns include possible political unrest and turmoil in non-Middle Eastern oil exporters (e.g., Latin America or Africa).

The behavior of the OPEC cartel is another major uncertainty. We identify two issues related to OPEC behavior: 1) internal cohesion of OPEC, and 2) installation of spare capacity. We have argued that at present OPEC does not act as a single short-run-profit-maximizing monopolist. A substantial increase in OPEC cohesion is both plausible and threatening. In contrast, if OPEC members, especially non-Persian Gulf OPEC members, install much more spare capacity than we have projected, then U.S. oil vulnerabilty would be substantially lower than we have projected.

The accuracy of oil demand growth forecasts is a third major area of uncertainty in the assessment. The recent history of forecasts of oil demand, not just oil price, do not instill confidence. In this study, we relied on demand forecasts for LDC countries based on analysis performed by the LBL/IES group. LBL projects continued rapid growth of oil demand in developing countries, at growth rates higher than the projections developed by oil companies and the government in their forecasts. While we believe that the LBL/IES oil demand forecasts are creditable and the most comprehensive, the issue of LDC oil demand clearly illustrates the large uncertainty in demand forecasts. Similarly, demand for oil in OECD countries is forecasted to be relatively flat during the next decade. Total demand for oil could vary by two to four million barrels/day if either of these basic trends do not materialize. If demand significantly exceeds expectations, spare capacity will disappear and vulnerability will increase. On the other hand, if demand falls significantly short of expectations, there will be more spare capacity and vulnerability will decrease for at least several years.

We also note two other areas of the analysis where there are significant uncertainties: 1) non-OPEC oil supply forecast, and 2) impact of changed oil market structure. In terms of the oil supply forecast, it is possible that the analysis incorrectly estimates the effect of low oil prices on non-OPEC supply. In addition, the discovery of major new non-OPEC oil reserves would affect the supply/demand balance as this study relies on oil company forecasts for production from non-OPEC nations. The second area of uncertainty is the effect in a future oil crisis of the changed structure of the oil market. We have made no allowance for any possible effects of two new developments. In contrast to the situation in 1973 and 1979, oil industry executives have personally experienced an oil price shock; this could affect their behavior in a future crisis. In addition, the oil market now includes a well-developed futures market.[14] Both of these new developments could lead to different dynamics in a future crisis, specifically less private stock building.

Finally, we have assumed in this study that strategic reserves would be used promptly. However, stated policy notwithstanding, this is not at all sure. We have already mentioned the need for governmental release decisions and the rejection in the U.S. of the use of options to make release automatic. To this should be added the observation that in a ''moderate'' crisis our vulnerability to a further market disturbance will be greatly increased. If we use the reserves, we will lose spare capacity, so there will be a temptation to save the reserves for a more severe crisis. Hence, releasing reserves may seem imprudent. Moreover, the oil market's reaction to the release of strategic stockpiles is not known. We have no experience with the market effects of such a release and should acknowledge the possibility that concern about the reserve's disappearance will prompt an offsetting building of private stocks.

Notes to Chapter 5

1. Cambridge Energy Research Associates, ''The Reshaping of the Oil Industry: Just Another Commodity'', 1985, p. 4; A.R. Tussing,''Oil Prices Are Still Too High'', *Energy Journal, 6:1* January 1985. It is also important to note some of the crucial differences between oil and most other commodities: long investment lead times and attempts at political management of supply to maintain price.
2. H.S. Rowen and J. P. Weyant, '' The Oil Price Collapse and Growing American Vulnerability'', (draft), 1986; H. G. Huntington and J. E. Eschbach, ''Energy Policy Issues and Macroeconomic Models'', Stanford University Energy Modeling Forum, September 1984, pp. 5-6.
3. H.S. Rowen and J. P. Weyant, '' The Oil Price Collapse and Growing American Vulnerability'', (draft), 1986, p. 22.
4. H.S. Rowen and J. P. Weyant, '' The Oil Price Collapse and Growing American Vulnerability'', (draft), 1986, p. 22.
5. The current situation (i.e., significant excess capacity) was brought about in part because of lower than expected demand.
6. Presumably, the spare production capacity in the subject area, country or group of countries would be unavailable during either an intentional or an unplanned interruption of production there.
7. A variant of the disruption depth index can be made by normalizing it by total world oil consumption rather than total free world oil consumption.
8. We have combined Iran and Iraq to illustrate the potential impact of an outright victory in their current war which leads to consolidated control by one side or the other.
9. The reciprocal of 3.8 is 0.26.
10. There is Congressional authorization for a fill rate of up to 0.075 MMBD.
11. See CERA, ''The Future of Oil Prices: The Perils of Prophecy," 1984; W. Goldstein, ''Price and Prospects for Oil'', *Energy Policy*, December 1985, pp. 524-534.
12. It also suggests that more private inventories will be available in a crisis for which there has been some period of warning.
13. H.S. Rowen and J. P. Weyant, '' The Oil Price Collapse and Growing American Vulnerability'', (draft), 1986.
14. Most analysts claim that an oil futures market should tend to mitigate some of the volatility in spot market prices that accompany a major supply disruption. However, the October 1987 stock market crash is not particularly reassuring on this issue.

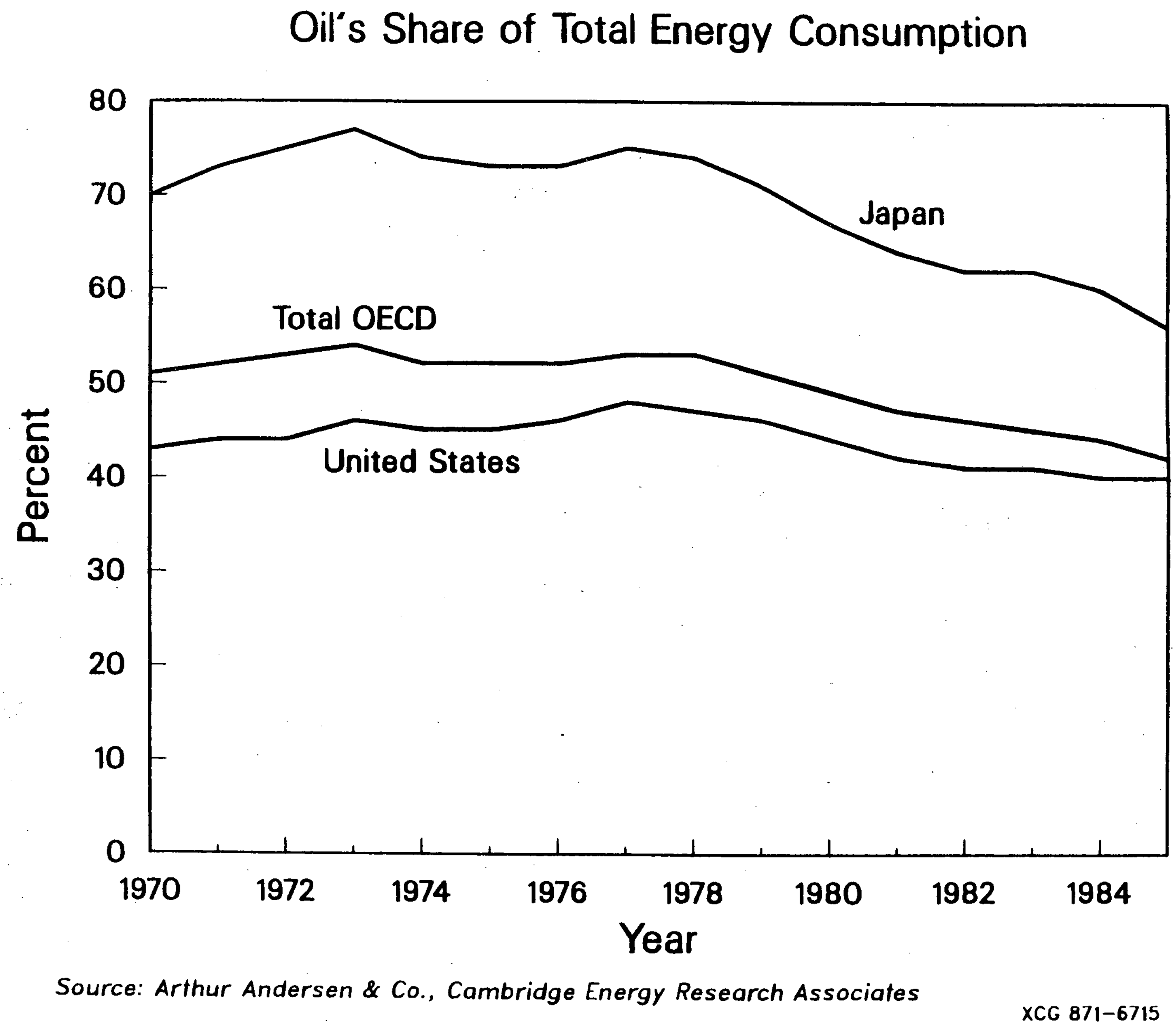


Figure 5-1. Oil's share of total energy consumption in U.S., Japan, and OECD countries.

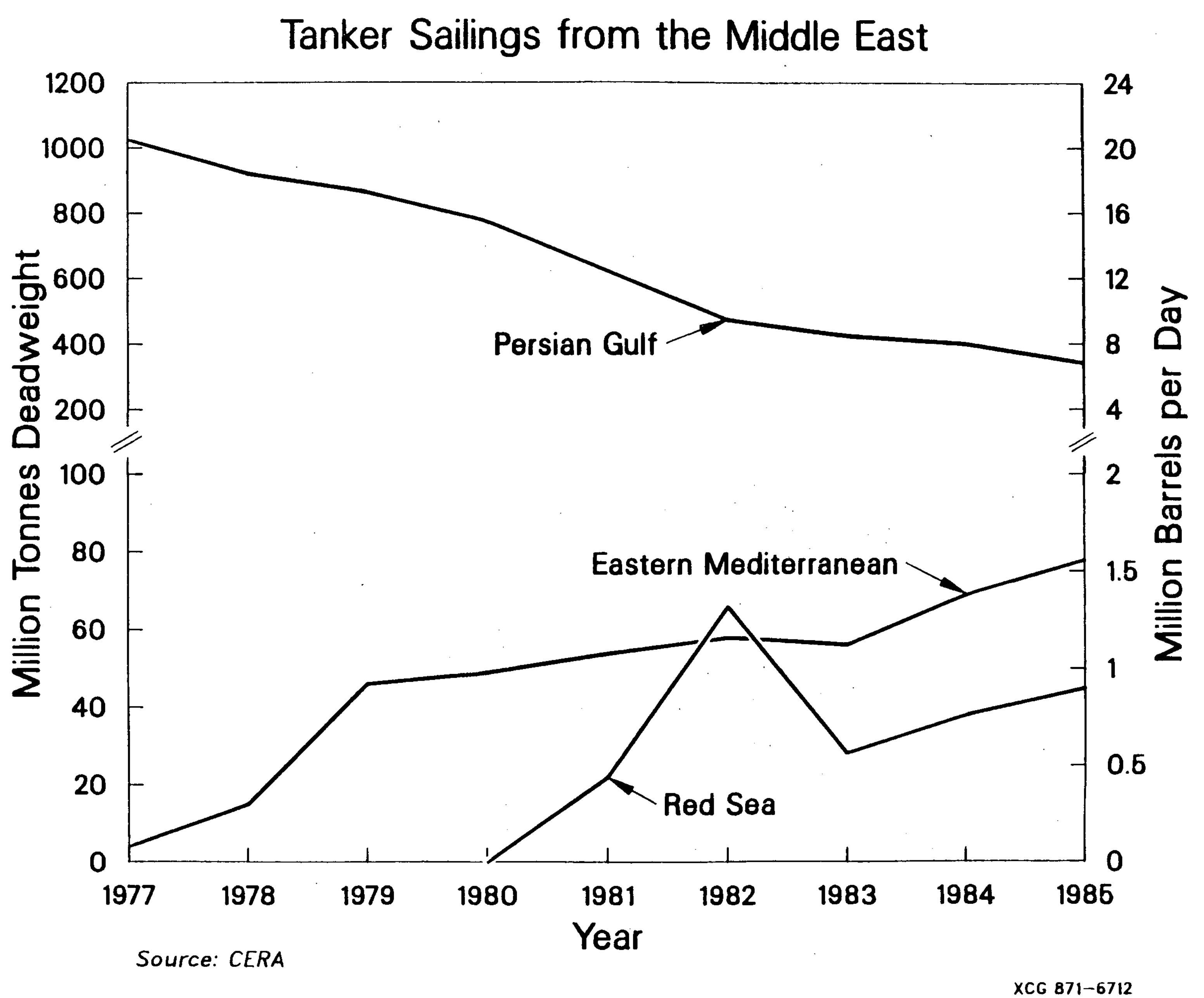


Figure 5-2. Middle East oil export transport system.

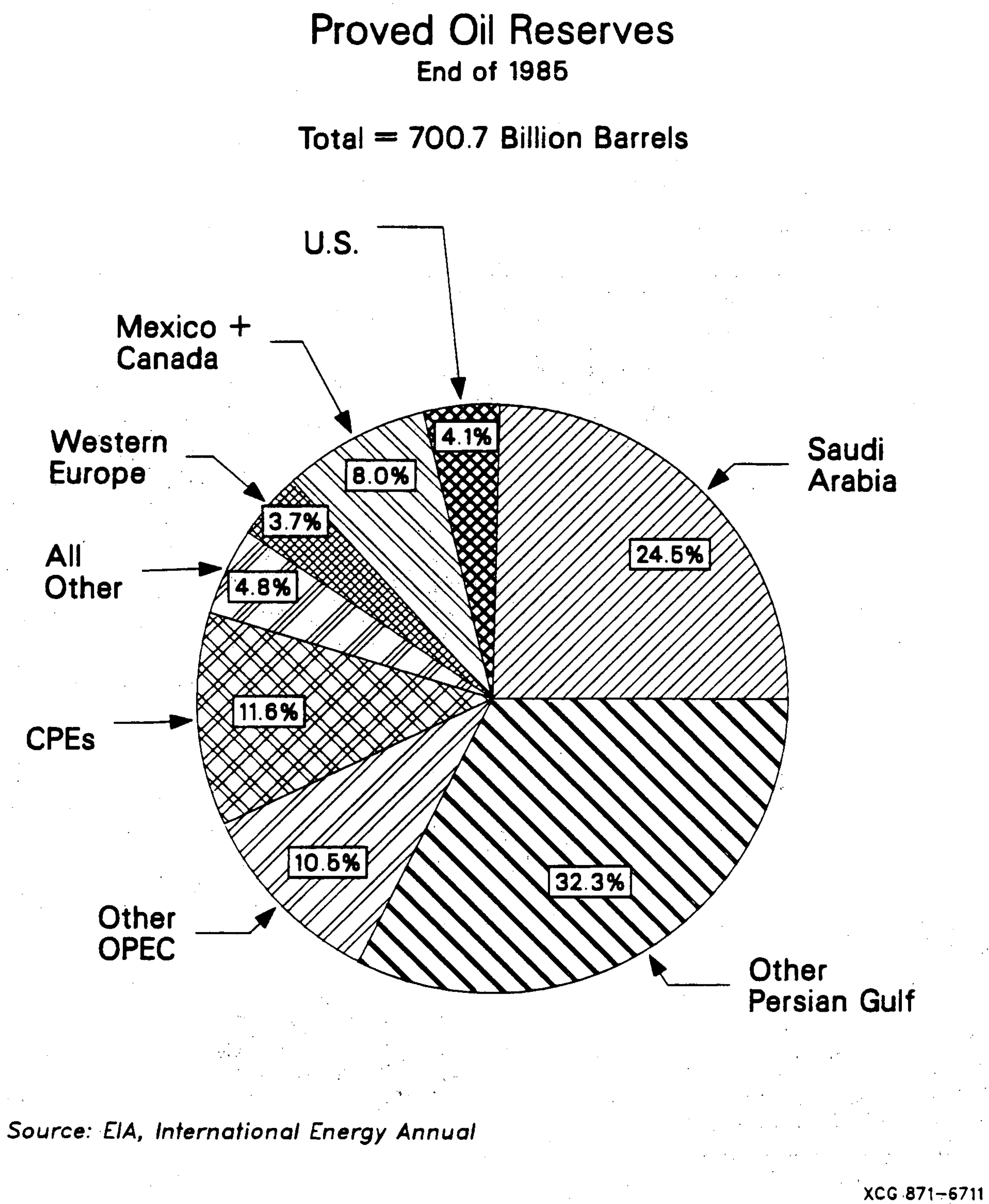


Figure 5-3. Proved oil reserves (1985).

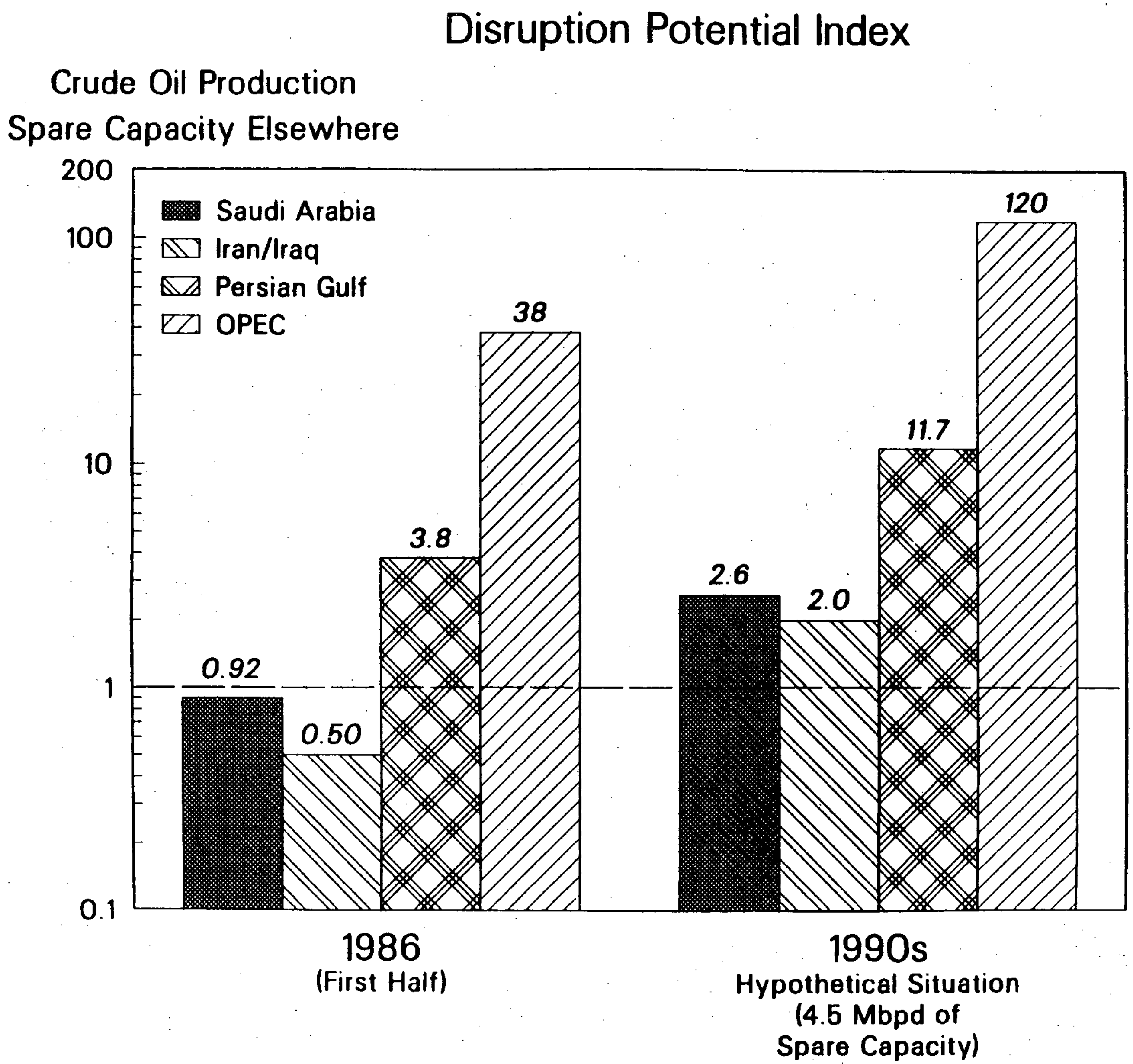
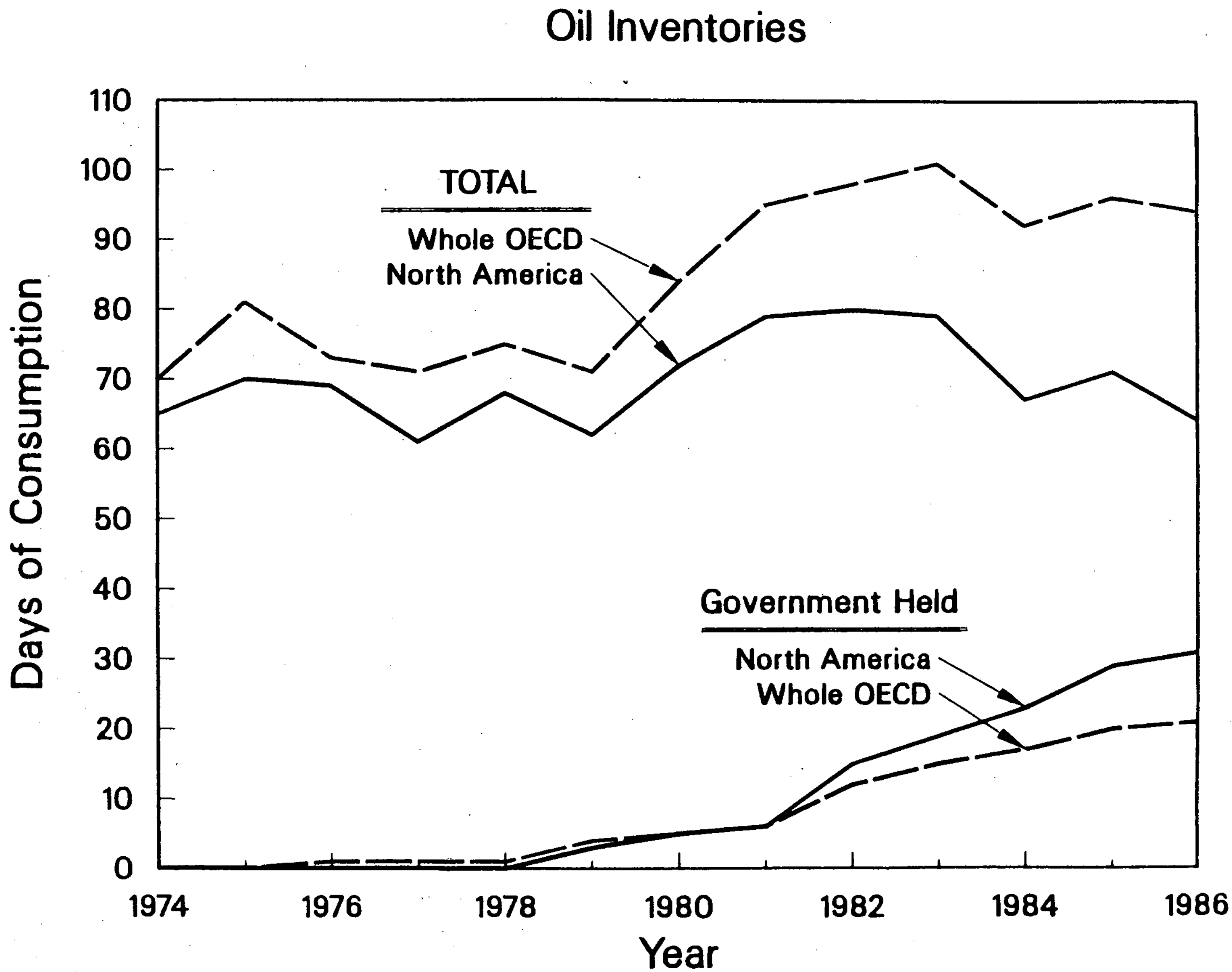


Figure 5-4. The disruption potential index is defined as the ratio of one country's (or a group of countries) oil production divided by spare production capacity in the rest of the world. It is an indicator of that entity's ability to bring the world oil market to disruption point (See Table 5-2 for details of calculation). We estimate values based on the current situation and for a hypothetical plausible case that could exist during the 1990s.



Source: IEA

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Figure 5-5. Government-held and private inventories of oil: North America and OECD.

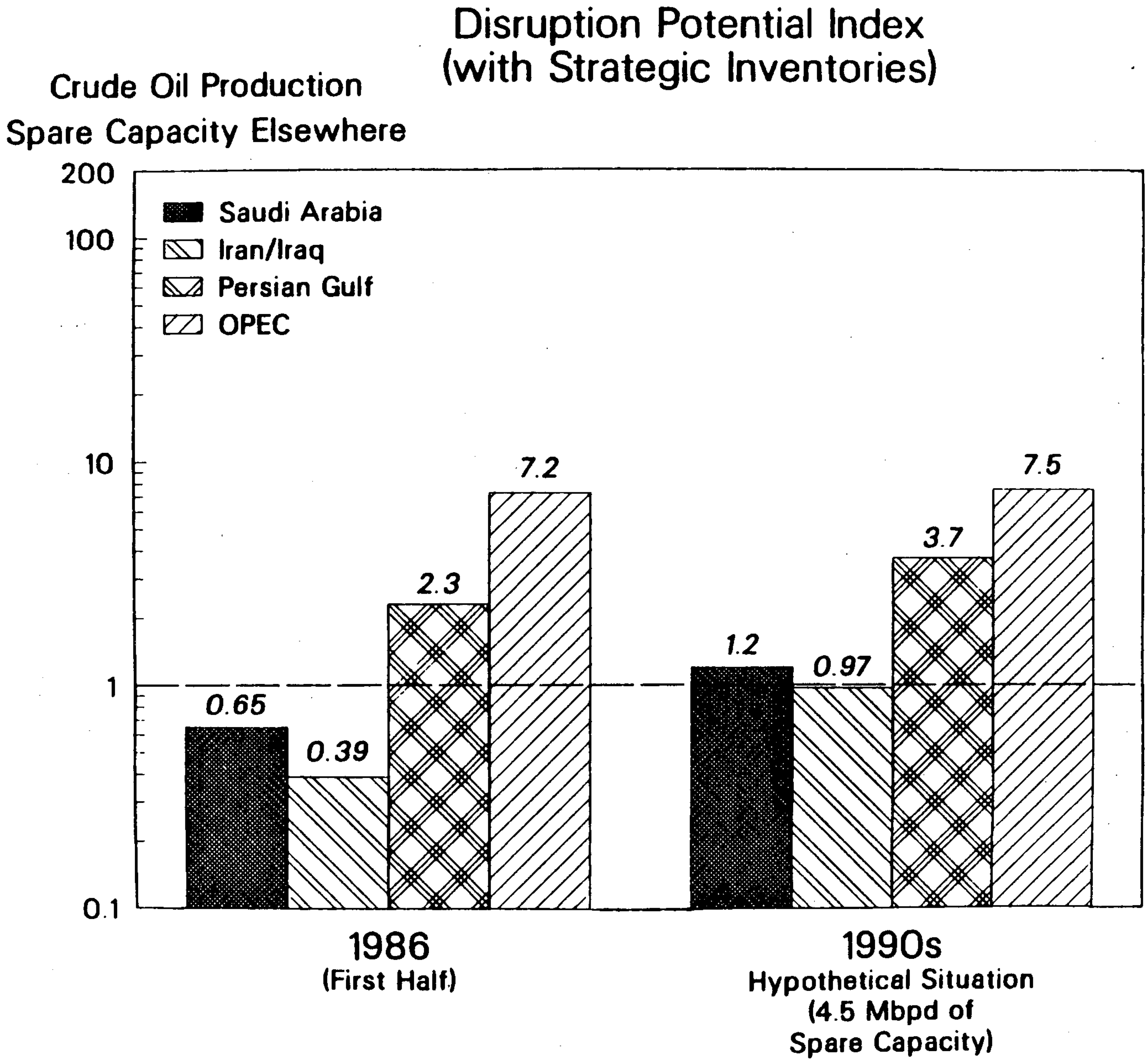


Figure 5-6. Disruption potential index values are calculated for current situation and for a situation during the 1990s based on the assumption that strategic inventories will be used to mitigate the impact of an oil supply disruption. Release of strategic oil stockpiles is assumed to increase spare capacity by 2 MMBD in 1986 and by 3 MMBD during the 1990s (see Table 5-4 for details of calculation).

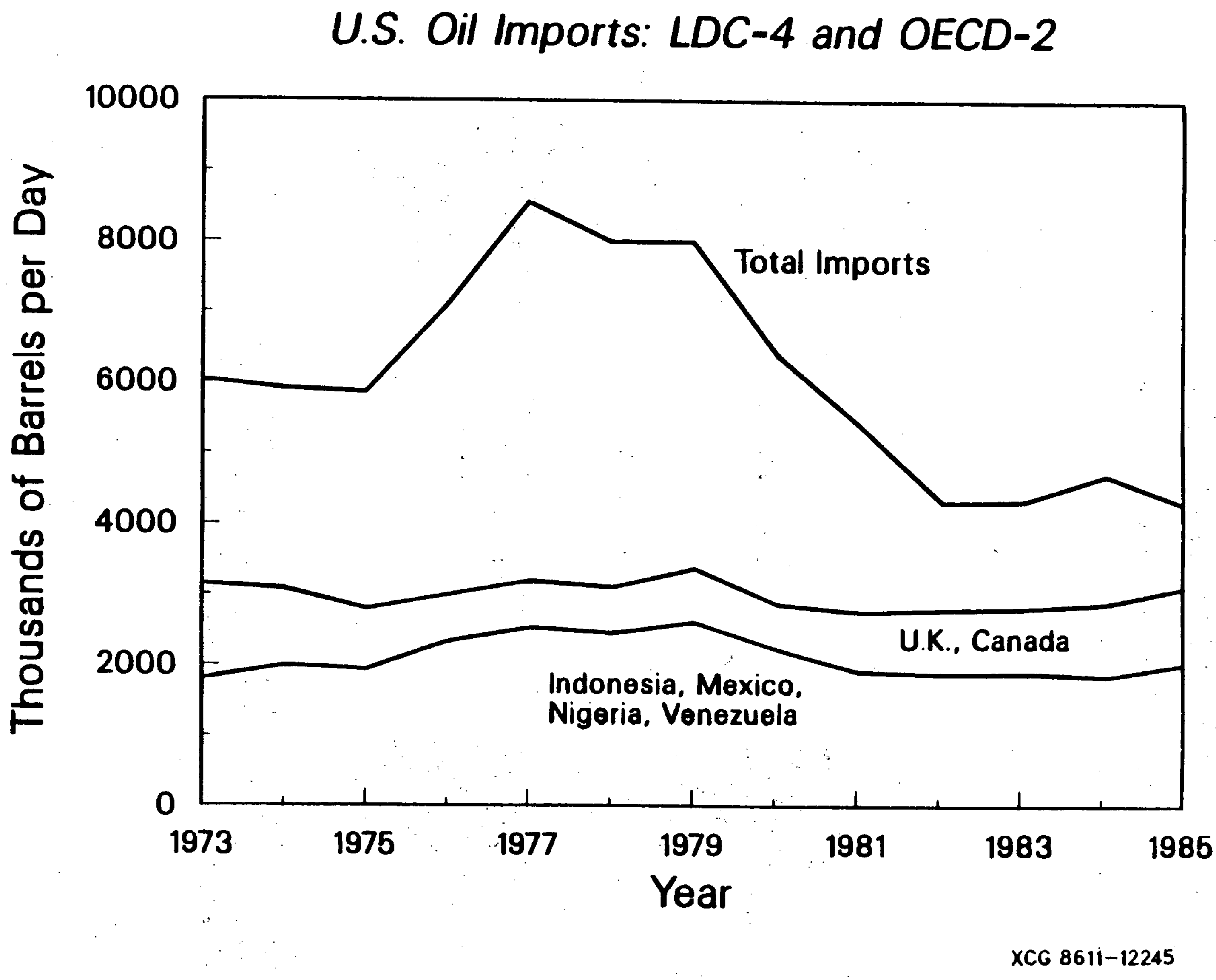


Figure 5-7. Share of U.S. oil imports supplied by four LDCs (Indonesia, Mexico, Nigeria, and Venezuela), Canada, and United Kingdom.

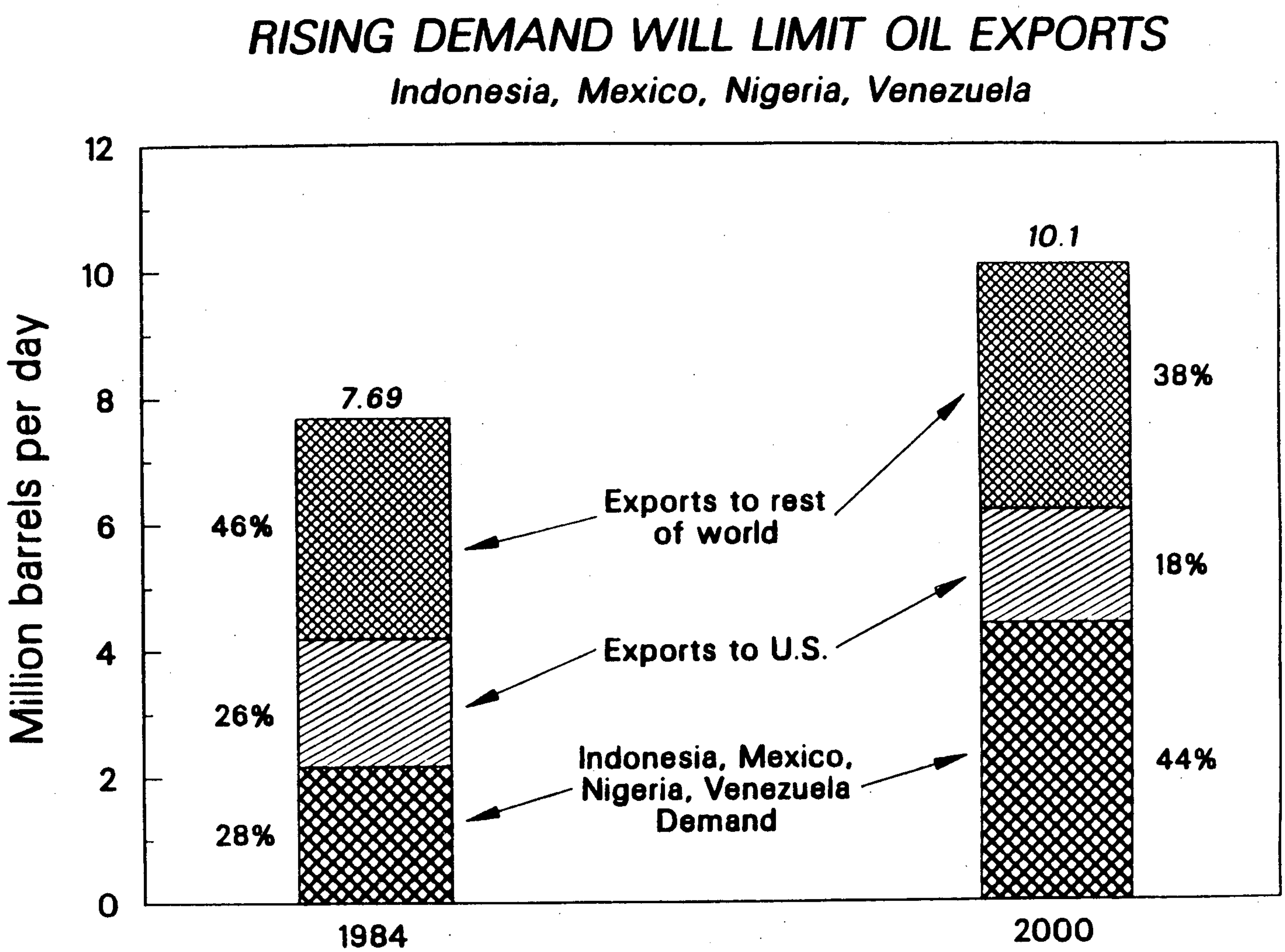
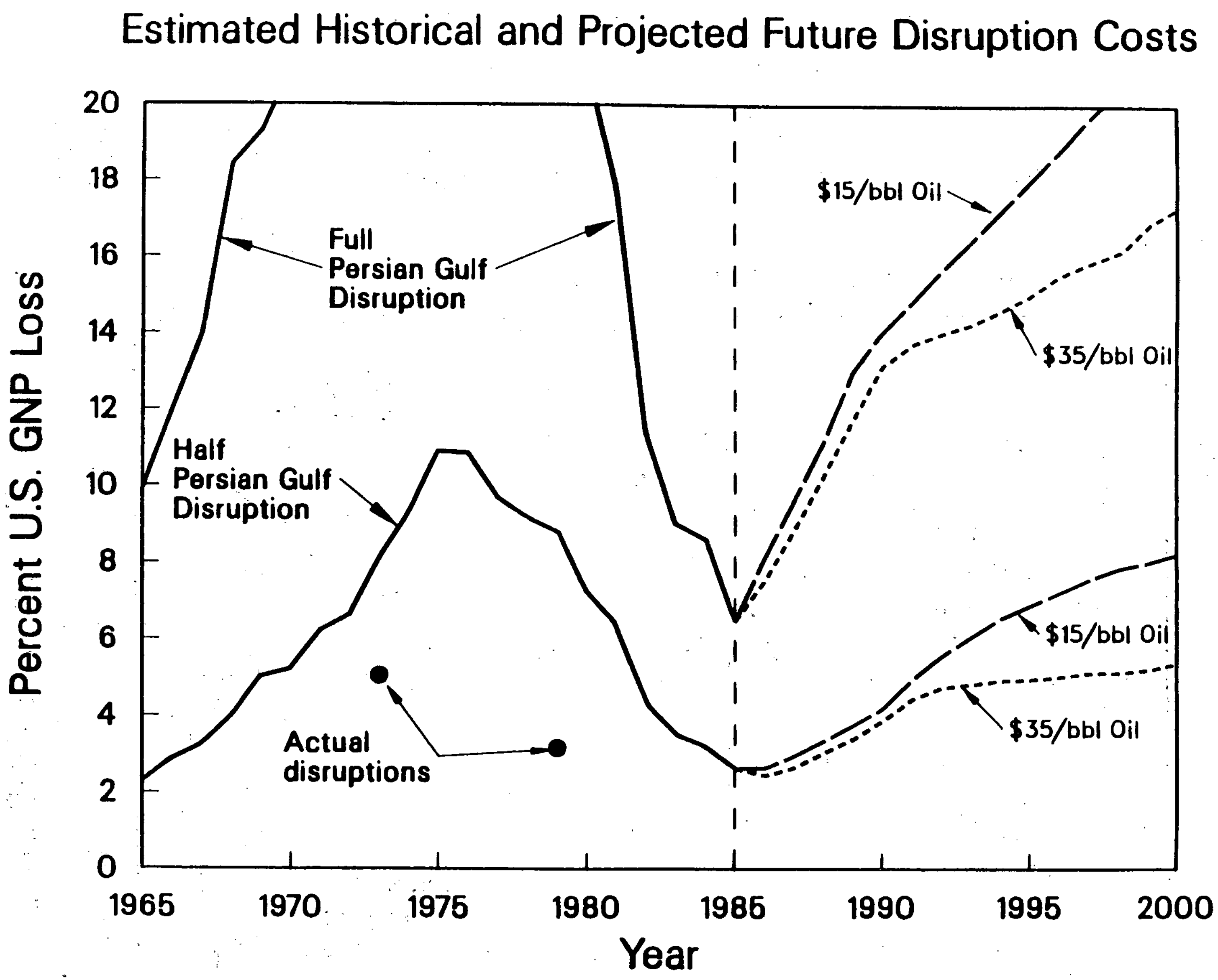
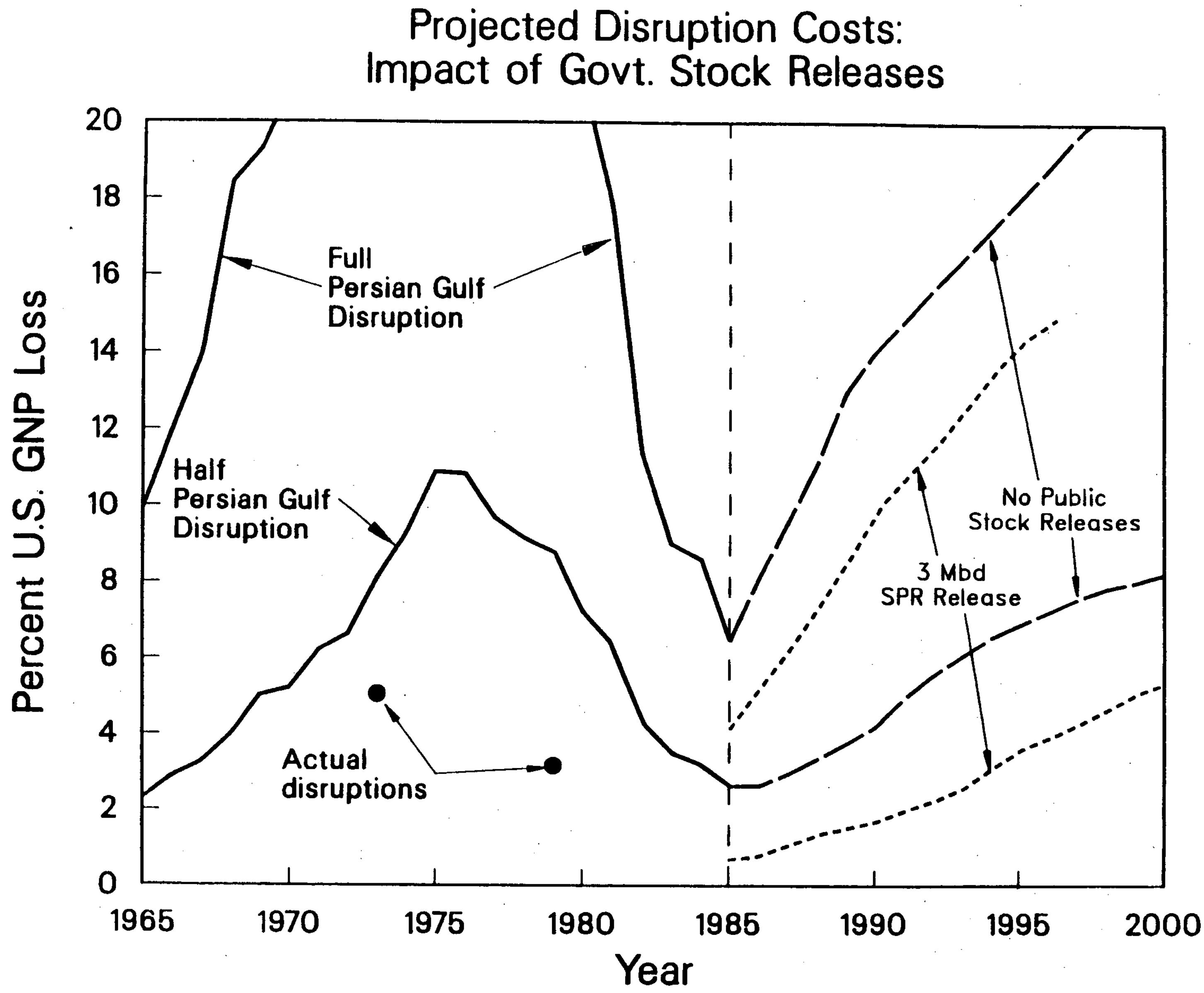


Figure 5-8. Projected oil supply and exports from Indonesia, Mexico, Nigeria, and Venezuela. Rising internal demand could limit exports from these LDCs that currently supply a significant fraction of imported U.S. oil.



Source: Rowen & Weyant, "The Oil Price Collapse and Growing American Vulnerability"

Figure 5-9. Estimated historical and projected costs of an oil supply disruption. Economic losses are expressed as a fraction of GNP loss for two oil price scenarios: $15/barrel and $35/barrel ($1986) in year 2000



Source: *Rowen & Weyant, "The Oil Price Collapse and Growing American Vulnerability"*

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Figure 5-10. Effect of releasing government-held strategic oil stocks on projected costs of an oil supply disruption.

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Appendix A

In this appendix, we summarize results from recent publically-available forecasts of the future world energy outlook (see Table A-1 and A-2). The forecasts were compiled from the following reports:

- Department of Energy (DOE/NEPP), "National Energy Policy Plan Projections to 2010 (final draft)", Washington DC, February 25, 1987
- Energy Information Administration (EIA), "Annual Energy Outlook 1985," February 1986 and "The Impact of Lower World Oil Prices and Alternative Energy Tax Proposals on the U.S. Economy" (draft), April 1986
- Gas Research Institute (GRI), "1986 GRI Baseline Projection of U.S. Energy Supply and Demand, 1986
- Ashland, "World Energy Outlook Through 2000", August 1986
- Chevron Corporation, "World Energy Outlook", June 1986; personal communication from Tom Burns, Chevron Corporate Planning and Analysis.

In reading and interpreting Tables A-1 and A-2, the following points should be noted:

1) Several of the forecasts were not accompanied by a detailed written discussion of their assumptions (e.g., the DOE forecast is a final draft for the next update of the National Energy Plan) or did not include information on all relevant categories (e.g., EIA does not have data on world oil demand).
2) There are some important definitional differences for various categories between forecasts. For example, GRI's forecast of U.S. oil production is lower than the other forecasts because it does not include production from natural gas liquids. GRI estimates non-OPEC natural gas liquid production (e.g., 1990, 2.56 MMBD; 2000, 2.39 MMBD) but it is not possible to break out the U.S. share from these aggregated values.
3) EIA's analysis of low oil prices was prepared in response to a request from the House Energy and Commerce to discuss the effects of falling oil prices. EIA used some key assumptions that were provided by the House Committee; hence the results should not be looked at as an "official" low oil price forecast. However, we have included the results of this analysis because it was conducted after the recent oil price collapse and more accurately reflects expectations about future oil prices than EIA's Annual Energy Outlook low oil price forecast of 1985, which was prepared prior to the price collapse.
4) There are significant differences in certain key assumptions in the low oil price forecasts that help explain differences in key results relative to the base case (e.g., U.S. energy demand). For example, Chevron uses lower economic growth rates in its low oil price case than in its base case forecast, which explains why U.S. energy demand is lower than the company's base case forecast (e.g., 89.1 vs. 92.3 Quads in 2000), although oil demand is higher (e.g., 17.9 vs. 17.0 MMBD in 2000). However, EIA uses similar real GNP growth rates in its base case and low oil price forecast. U.S. energy and oil demand are higher in the low oil price case compared to the base case. EIA forecasts that oil demand will increase due to the lower prices, and in the long run, further increases will result from reduced profitability of

conservation technologies and an increase in vehicle travel. Total energy consumption will also increase because of lower prices, and because of the positive impact from the low prices on the economy, personal real income, and business activity. Ashland's low oil price scenario is based on several key assumptions that are not necessarily embodied in the other two low oil price forecasts that we analyzed. It assumes that oil prices drop to about $5/barrel in 1987 driven by the disintegration of OPEC or a Saudi decision to abandon production controls and produce at near capacity. After this sharp downward drop, oil prices climb to about $13/barrel ($1986) by 1990 and then to $25/barrel by the year 2000. In addition, this scenario assumes that some major consuming countries levy additional tariffs or product taxes to moderate growth in demand.

Table A-1. World Energy Forecasts: Higher Oil Price Case

	DOE (NEPP-VI)			EIA			GRI			ASHLAND			CHEVRON		
	1990	1995	2000	1990	1995	2000	1990	1995	2000	1990	1995	2000	1990	1995	2000
Oil Prices[a] (1986 $/bbl)	20.3	26.1	32.5	27.0	30.0	---	20.4	23.1	26.8	17.1	20.0	28.9	---	28.0	35.0
U.S. Oil Demand (MMBD)	17.0	17.0	17.1	16.1	16.5	---	16.4	17.1	18.1	17.5	18.3	17.8	---	16.6	17.0
World Oil Demand (MMBD)	50.2	52.1	54.6[b]	---	---	---	48.6	51.4	55.7[c]	49.8	52.8	52.6[d]	48.0	50.9	54.1
U.S. Domestic Oil Production[e] (MMBD)	9.4	8.0	7.2	9.8	8.2	---	8.3	7.2	6.3	---	---	---	7.9	8.1	7.3
U.S. Energy Demand (Quads)	83.1	89.0	94.0	80.4	84.3	---	---	---	---	---	---	---	---	87.8	92.3
% U.S. Imports[f]	42	49	55	35	47	---	---	---	---	---	---	---	38	51	57
% World Oil Supplied by OPEC	46	52	56[g]	---	---	---	43	50	56[h]	43.5	50.5	51[i]	38	48	53[j]

[a]EIA and GRI in 1985 dollars
[b]Includes coal liquids and NGL
[c]Includes crude, condensate, NGL, tar sands, shale and other synfuels (losses), refinery gains, inventory changes, and net imports from communist countries
[d]Includes NGL
[e]GRI does not include natural gas liquids (NGL)
[f]Includes SPR
[g]OPEC supply includes EOR, heavy oil, tar sands, shale oil, and NGL
[h]Includes SPR
[i]OPEC supply does not include NGL or processing gain
[j]OPEC supply includes crude only

Table A-2. World Energy Forecasts: Low Oil Price Case

	EIA			ASHLAND			CHEVRON		
	1990	1995	2000	1990	1995	2000	1990	1995	2000
Oil Prices (1986 $/bbl)	17.0	20.0[a]	---	13.2	17.6	25.5	---	15.0	20.0
U.S. Oil Demand (MMBD)	17.1	18.2	---	18.2	19.2	20.3	---	17.7	17.9
World Oil Demand (MMBD)	---	---	---	52.7	55.0	56.0[d]	---	52.6	54.9
U.S. Domestic Oil Production (MMBD)	7.2	5.0[b]	---	7.1	6.7	5.1[e]	---	6.0	5.4[f]
U.S. Energy Demand (Quads)	82.9	86.9	---	---	---	---	---	86.6	89.1
% U.S. Imports	43	60[c]	---	48	54	64	---	66	70
% World Oil Supplied by OPEC	---	---	---	---	---	---	---	62	63[g]

[a] $1985 per barrel
[b] Includes NGL
[c] Includes SPR
[d] Includes NGL
[e] Includes crude and condensate
[f] Includes crude only
[g] OPEC supply includes crude only

Appendix B

Increasing Oil Demand in Developing Countries and U.S. Oil Security

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1. Introduction

This paper focuses on the rapidly increasing demand for oil in the developing countries, its impact on tightening the oil market and increasing U.S. reliance on that market and on insecure supplies imported from politically troubled countries. The forecast of oil demand in developing countries is based on a detailed analysis of 18 developing countries (LDCs) in Asia, Latin America, and West Africa. Together, the study countries account for more than 70 percent of primary energy and oil demand in LDCs. The forecast shows oil demand increasing at a rate of 3.8 percent a year, which is significantly higher than forecasts published by DOE, IEA and oil companies.

LDCs account for 23 percent of world energy* demand, which is about as much as Western Europe. This share is increasing, but there is relatively little knowledge about the energy markets and the patterns of demand growth in LDCs, and hence, about the future impact of LDC energy demand on the use and trade of petroleum and other forms of energy. Over the past few years, the International Energy Studies Group of Lawrence Berkeley Laboratory has developed a data base for a growing number of LDCs. The purpose of our research on LDC energy demand is to reduce the uncertainty surrounding the future of energy demand in LDCs and to understand better its implications on the availability of oil to the U.S. and the world market. Our analysis of energy demand looks within each country at the changes in energy demand and the structural factors involved for four sectors: industry, transportation, residential/commercial, and electricity generation. The historical analysis covers the period 1973-1984, with emphasis on the period following the 1979 oil price increase.

1.1. The Study Countries

The countries in our study are:

Asia: Bangladesh, China (P.R.C.), India, Indonesia, South Korea, Malaysia, Pakistan, Philippines, Taiwan,** and Thailand,

* Throughout the analysis, the term "energy" refers to commercial fuels (i.e., not including biomass). All monetary figures are expressed in US dollars of 1980. Conversions to dollars were made from series in constant currency for each country.

Latin America: Argentina, Brazil, Mexico and Venezuela, and
West Africa: Ivory Coast, Senegal, Nigeria and Morocco.

The 10 countries in Asia account for over 90 percent of Asian*** LDC energy consumption. China, with 45 percent of the region's population and 61 percent of energy consumption, dominates the regional picture when it is included. The four countries in Latin America account for 73 percent of the total energy use in that region, while the four countries in West Africa account for 75 percent of energy use in all of West Africa. (Although the four countries in West Africa account for less than one-tenth of the energy demand in each of the other two regions, their patterns of energy demand are important because they reveal some unexpected relationships between energy use and economic activity.)

The size of and recent growth in energy consumption for each group of countries relative to each other and to parts of the industrialized world is shown in Table B-1. The size of their oil demand in relation to overall oil demand in the LDCs is shown in Figure 1.

** Inclusion of Taiwan as a country does not imply any judgement by the authors as to its political status.

*** - Asia as defined here includes developing countries east of the "Middle East" and south of the USSR.

Table B-1. **LDC Energy Demand in Context**

	1984 Primary Energy Consumption (million TOE)	*Avg. Annual Growth in Energy Consumption 1973-84*
Asia-10	804	5.9%
China	492	5.4%
India	137	5.5%
Other 8	175	7.6%
Latin America-4	309	5.8%
West Africa-4	19	4.6%*
Rest of Africa[a]	170	6.0%
Japan[a]	370	0.5%
Western Europe[a]	1203	0.0%
United States[b]	1973	0.2%
Centrally Planned Economies*	1883	3.3%

Source:

[a] 1985 Statistical Review of World Energy, British Petroleum Co., 1986..

[b] Monthly Energy Review, Energy Information Administration, DOE.

* From 1977 to 1984.

2. Developing and Developed Countries: Different Paths for Energy Demand

The countries that fall into the category generally referred to as the LDCs are a diverse group, and most generalizations do not apply in all cases. Nonetheless, the main feature that distinguishes the LDCs from the industrialized countries (whether those in the OECD or the industrial centrally-planned economies) is that they are still undergoing industrialization and urbanization.

The increasing concentration of population in urban areas has put continuous upward pressure on the supply of commercial fuels, especially petroleum products used for cooking and for transportation. For cooking, the pattern that emerges is a rise in use of kerosene with income within lower-income groups. As income increases further use of kerosene gives way to use of liquified petroleum gas (LPG) and/or electricity. Additionally, in response to the increasing number of vehicles needed to provide personal and freight transport in urban areas, the demand for gasoline and diesel grows at unusually high rates.

The continuing industrialization and urbanization in the LDCs has placed them in a very different position from the industrialized countries vis a vis energy demand. In the OECD countries, one response to higher oil prices has been improved efficiency of energy use. Demand has stayed at about the same level despite economic growth (Figure 2). This is partly due to response to higher energy prices, and partly due to the nature of the economic growth (increasingly more oriented toward services). In the LDCs, there was some response to higher energy prices, but the forces of industrialization and urbanization continued to place upward pressure on commercial energy demand. This growth and the lack of it in the OECD countries caused the LDC share of world oil demand to increase from 14 percent in 1970 to 23 percent in 1985. During the same period, the share of the OECD countries fell from 71 to 57 percent (Figure 2).

The future expansion of world energy demand will continue to be generated mostly in the LDCs. While OECD countries enjoy high incomes per capita, stable population, and a mature industrial sector, the LDCs are in need of substantial economic growth and, therefore, high growth of energy and oil use, in order to provide for fast-increasing populations, especially in large urban areas, and to support the development of domestic industries.

3. Energy Demand and GDP

The growth trends for energy use and GDP have been remarkably varied since 1973. Energy use per capita rose at an average of 3.9% per year in Asia, 3.4 percent in Latin America, and at 4.9% per year in West Africa (from 1977 to 1983). In Asia, energy consumption increased with growth in GDP per capita. In Latin America it increased at a slower rate but with little or no change in GDP per capita. In West Africa it increased at the fastest rate, despite a decline in GDP per capita.

Table B-2 shows the changes in the energy/GDP ratios for the study countries. There has been considerable variation within each region. In a few countries, GDP grew faster than energy demand (China, Philippines, Thailand), but in the majority of countries, energy demand grew faster than GDP. Countries in Asia had less growth in the energy/GDP ratio than those in Latin America and Africa. The increased debt burden, coupled with adverse effects of the second oil price increase constrained economic development in Latin America, and the over-reliance on export of a single commodity combined with poor weather had a crippling effect on the economies in Africa.

Table B-2. **Primary Energy and Oil Demand per Unit GDP**
(TOE per 1980 Million US $)

	ENERGY			OIL		
	1973	*1984*	*AAGR*	*1973*	*1984*	*AAGR*
Asia						
Bangladesh	-	273	-	-	100	-
China	1607	1400	-1.3%	302	249	-1.8%
India	677	792	1.4%	222	236	0.6%
Indonesia	246	353	3.3%	215	257	1.6%
Korea	608	634	0.4%	390	347	-1.1%
Malaysia	344	356	0.3%	323	309	-0.4%
Pakistan	404	638	4.2%	191	231	1.7%
Philippines	467	346	-2.7%	446	250	-5.3%
Taiwan	605	621	0.2%	417	339	-1.9%
Thailand	415	382	-0.8%	379	284	-2.6%
Average	911	967	0.5%	289	260	-0.9%
Latin America						
Argentina	238	291	1.8%	165	151	-0.8%
Brazil	536	676	2.1%	345	326	-0.5%
Mexico	442	564	2.2%	249	305	1.8%
Venezuela	825	1361	4.6%	272	513	5.8%
Average	428	573	2.7%	249	283	1.2%
West Africa						
Ivory Coast	110	136	3.0%	102	96	-0.9%
Morocco	276	279	0.2%	217	236	1.2%
Nigeria	93	209	11.6%	63	156	13.0%
Senegal	382	455	2.5%	382	455	2.5%
Average	125	219	8.0%	93	170	8.6%

Table B-2 also shows the change in the oil/GDP ratios for each study country. For most oil-importing countries this ratio declined. The few exceptions were countries in West Africa and India and Pakistan. In West Africa, the ratio increased since there was no other substitute fuel available to replace oil. In Pakistan, it increased as oil use grew unabated because the country prospered from the remittances of workers who had taken up jobs in the Middle East. The ratio also increased in the four major exporters -- Indonesia, Mexico, Nigeria and Venezuela, because of continued low price of oil products and the macroeconomic stimulus provided by higher earnings from oil exports.

4. Different Growth Among the Fuels

Trends in energy and oil demand in LDCs were different before and after the oil price increase of 1979. From the early 1970s up to 1978, energy and oil demand increased at rates in excess of 7 percent in all of the regions (Table B-3). In Asia, oil demand outgrew aggregate demand for energy in the period 1973-78. In Latin America, the development of hydroelectric resources kept the growth of aggregate demand for energy growing much faster than petroleum demand which, nevertheless, increased at an average yearly rate of 7 percent. After 1978, in the presence of higher oil prices and ensuing economic difficulties for all countries, demand for all fuels slowed down considerably and, in some cases, stagnated or declined.

Table B-3: Primary Energy and Oil Demand

Region	1973	1978	AAGR	1984	AAGR
Energy					
Asia	423	619	7.6%	804	4.4%
Latin America	136	254	12.5%	309	3.3%
West Africa		14		18.9	5.1%
TOTAL		870		1072	4.2%
Oil					
Asia	134	216	9.3%	234	1.3%
Latin America	95	135	7.0%	152	2.0%
West Africa		11		16.5	5.8%
TOTAL		366		400	1.8%

The share of oil in primary energy demand declined in most countries (Table B-4). It increased only in Venezuela and Nigeria, two of the major oil exporters and in Morocco. The combined share of oil in primary energy supply for Asia and Latin America declined from 41 percent in 1973 to 35 percent in 1984. The decline was more pronounced in Latin America than in Asia due to greater availability of natural gas and hydroelectricity to replace petroleum products in industry and in electricity generation. In both regions, the largest reductions in petroleum demand occurred in the countries with heaviest dependence on imported oil, Brazil and Taiwan.

Table B-4. Share of Oil in Total Commercial Energy Demand (percent)

	1973	*1984*
Asia		
Bangladesh	52[a]	37
China	19	19
India	33	30
Indonesia	87	73
Korea	64	55
Malaysia	94	87
Pakistan	47	36
Philippines	96	72
Taiwan	69	55
Thailand	91	75
Average (w. China)	32	29
Average (w/o China)	55	47
Latin America		
Argentina	73	52
Brasil	64	48
Mexico	56	54
Venezuela	31	38
Average	58	49
West Africa		
Ivory Coast	93[a]	89
Morocco	79[a]	87
Nigeria	70	80
Senegal	100	100
Average	75	83

[a] 1977

The use of coal in Asia and Latin America increased faster than that of energy between 1973 and 1984. Its use declined slightly in West Africa. Excluding China, it accounted for 19 percent of the primary energy demand in 1984 in the three regions combined. Coal accounts for 60% of energy demand in Asia due largely to its heavy use in China, (60 percent in 1984), but for only 3 percent of the share in Latin America or West Africa. Coal use in Asia is concentrated in China and India, which have abundant domestic coal resources and have used it for decades as the primary fuel.

Use of natural gas grew faster than that of coal or oil in each of the three study regions. Excluding China, it accounted for 16 percent of the primary energy demand in the study countries in 1984. It contributes 25 percent (in 1984) of total energy demand in Latin America. Its share in West Africa and Asia is less than 10 percent, but is growing rapidly. The increased exploration since the mid-1970s has added substantially to the natural gas reserves of many countries, both in the form of free natural gas and as associated gas produced in oil fields.

Primary energy sources for electricity generation, mainly hydropower, account for 20 percent of the total energy demand in Latin America, while in Asia and West Africa that share is about 5 percent (it is 9 percent for all Africa). Although West Africa has substantial hydroelectric resources, their development has been constrained by capital availability and by the relatively small size of the markets, which poses further constraints to the large-scale investments usually required for hydroelectric power plants. The share of nuclear power has increased in Taiwan, Korea and India with the addition of new units, while the Philippines has added over 1000 MW of geothermal power.

5. Forecast of Oil Demand

The historical analysis indicates that oil and energy consumption continued to increase in the developing countries in both vibrant and stagnant economies. Oil and energy demand per capita increased even during periods of stagnant GDP per capita in the Latin American countries and declining GDP per capita in the oil exporting countries of the Middle East, and in Nigeria. Aggregate oil demand in the LDCs as a group increased through periods of rising and falling prices. After 1979, the growth rate of oil demand slowed considerably, mainly due to the use of substitute fuels and better management of demand in the more industrialized countries. In the poorer countries growth in oil demand continued since substitute fuels were not readily available or affordable. In the future, however, countries that import oil are likely to face a different set of issues and a different pattern of growth than those that export oil.

For oil importers, there are indications that the decline in petroleum intensity observed in the 1979-83 period may have bottomed out and that an increase in petroleum intensity could happen in the near future. The intensity may increase in the short run, if industry and power sectors revert to using fuel oil while its price remains low. Economic growth in these countries should benefit from the lower price of oil; directly, through lower payments for imported oil and indirectly, through higher exports to the industrialized countries, whose economies are also benefiting from lower oil prices. In the long run, a tighter oil market will result in a higher oil price which will restrict economic growth in the importing countries. This will lower the rate of growth in the demand for oil in these countries.

For oil exporters, the issue is to achieve a balance between domestic and foreign markets. The sale of petroleum and its derivatives is the main source of foreign exchange, and accounts for a share ranging from two-thirds to three- quarters of total government revenues in these countries. As world oil prices decline and, in some cases, approach production costs, these countries will need substantial increases in exports to maintain the necessary inflow of foreign exchange. In the short-run, with low oil prices, economic growth in these countries has stagnated. However, growth in oil and energy consumption in these countries is less coupled to the growth in GDP (personal income and GDP are loosely connected in the Middle East exporting countries) than in the importing countries and growth in demand for oil has continued during the past few years. (Higher prices of petroleum products in some countries have had the effect of restraining demand for products.) The growth in oil and energy demand will resume if the prices of petroleum products are lowered in these countries to match the worldwide drop in prices. (Indonesia decreased the price of diesel and fuel oil by ten percent last July.) As the oil market tightens in the next few years, these countries will benefit from the higher price of oil and the corresponding economic growth.

Assuming that the demand for oil in the importing and exporting countries will be influenced by the factors outlined above, we forecast the oil demand by region (Table B-5) based on detailed individual forecasts for each of the 13 study countries in Asia and Latin America, and for Nigeria.

Table B-5
Oil Demand Forecast by Region
(Million Barrels Per Day)

	1990	2000
Asia	4.5	6.3
China	2.3	3.5
Africa	1.9	2.8
Latin America	5.4	8.1
Middle East	2.3	3.2
TOTAL	16.2*	24.0*

* - Figures may not add due to rounding errors.

We have forecast the demand for oil and energy for each major sector -- industry, transport, power and residential/commercial for 1990 and 2000. These forecasts assume that price of oil will remain unchanged till 1990 and then will increase steadily to $34 dollars/barrel by 2000.

The forecast shows oil demand increasing at a rate of 3.8 percent a year to 1990 and at a rate of 3.9 percent a year after that. This growth rate is significantly higher than that forecast by other institutions. The forecasts published by DOE, IEA and oil companies show lower growth rates and hence lower demand for oil in 1990 and 2000 (see Figure 3). The growth of oil demand in the OECD countries is consistent with that forecast by other institutions. Combined with the oil demand forecast for the Centrally Planned Economies (CPEs) (Reference zz), the growth in the demand for oil will occur faster than projected by DOE and will lead to a tightening of the world oil market sooner than forecast.

6. U.S. Oil Imports

The amount of oil imported by the United States has declined substantially since 1979, in keeping with the overall decline in the demand for oil. The level of imported oil peaked in 1977 at about 8.8 million barrels a day (Table B-6). Imports from OPEC countries accounted for about 71 percent of this oil and Arab-OPEC countries accounted for 36 percent. Saudi Arabia was the single largest supplier of oil at 1.4 million barrels a day. By 1985, the share of OPEC oil had dropped to 36 percent and that of Arab-OPEC countries to 9 percent.

Table B-6
U.S. Crude Oil and Products Imports

	1977	1985	1986*
		(Million Barrels/Day)	
OPEC	6.19	1.83	2.69
Arab-OPEC	3.19	0.47	1.11
Saudi Arabia	1.38	0.17	0.66
Total Imports	8.81	5.07	5.97
Net Imports	8.57	4.29	5.20

NOTE: * - 1986 figures are for January through September only.

Much of the decline in the supplies from OPEC sources was made up by two new suppliers -- Mexico and the United Kingdom. In 1977, Mexico and U.K. supplied only 180 and 125 thousand barrels a day respectively. By 1985, these supplies increased to 815 and 310 thousand barrels a day. As a result, Mexico was the single largest supplier of oil to the United States in 1985. Venezuela at 605 thousand barrels a day, Indonesia at 315, Nigeria at 295, and Canada at 770 made up bulk of the remaining oil imported by the United States in 1985. Combined with the former two countries, these six countries supplied about 60 percent of the total oil and 71 percent of the net oil imported in 1985.

The sharp decline in the price of oil in 1986 has already stimulated demand for oil in the U.S., and resulted in lower domestic production. As a result, oil imports in the first nine months of 1986 averaged around 6.0 million barrels a day, or 900,000 barrels a day more than in 1985. Most of the additional imports came from the Arab-OPEC countries. The share of OPEC countries increased to 45 percent from 36 percent a year earlier: that of Arab-OPEC countries increased to 19 percent from 9 percent. The share of the aforementioned six non-Arab countries declined to about 55 percent.

7. Oil Demand in Indonesia, Mexico, Nigeria and Venezuela

These four countries accounted for almost 40 percent of the oil imported by the United States in 1985. It is unlikely that more oil will be forthcoming from these countries in 2000 since the internal demand for oil in these countries will likely outstrip their ability to produce more oil.

The demand for oil in these four LDCs was around 2.2 million barrels a day in 1984. LBL projects this to double to 4.4 million barrels a day in 2000. Projected demand in Indonesia will approach 1.2 million barrels a day or about 75 percent of their peak production, thus reducing the amount of oil available for export. Projected demand in Mexico will approach 2.2 million barrels a day or about 67 percent of its past peak production. This will restrict the amount of oil available for export unless production is expanded and the inefficient domestic use of oil is managed better. Reserves are available but will require extensive capital investment which may not be forthcoming. Demand in Nigeria will range from 400 to 600 thousand barrels a day or less than half their peak production. However, given the difficult political and financial situation in Nigeria and the small likelihood of discovering new reserves, the diminishing exports may pose a threat to political stability and to continued production. Demand in Venezuela, a country with smaller population than the above three, will approach 600 thousand barrels a day. The Venezuelan reserves are mainly in heavy oil which would require extensive cracking to meet the growing demand for middle distillates in the world market.

Figure 4 shows the disposition of the oil produced by the four countries in 1984. About 28 percent of the oil was consumed for domestic needs and about 26 percent was exported to the United States. In 1984, the U.S. imports of oil accounted for about 20 percent of the worldwide imports of oil, yet the U.S. received 36 percent of the exports of these 4 countries. This indicates an already heavy reliance on oil from these 4 countries.

By 2000, domestic demand will consume about 44 percent of the oil produced in these countries reducing the fraction available for export to only 56 percent.(Production forecasts are based on estimates provided by oil companies.) Since the world oil demand and world oil imports will rise faster, the share of their oil exported to the U.S. will decline in the future. Our projections assume that the decline will be in the same proportion.

8. Increase in Reliance on Arab-OPEC Oil

Figure 5 shows the sources of oil supply to the U.S. in 1985 and projected sources in 2000. In 1985, domestic production supplied much of the U.S. oil. Imports from Arab-OPEC countries accounting for 9 percent of the total supply. The total demand was 14.9 million barrels a day. Under a low-price scenario, DOE projects this demand to increase to 17.9 million barrels a day by 2000. Domestic production in the U.S. will account for only 40 percent of this demand.

LBL projects the exports from Indonesia, Nigeria, Mexico and Venezuela to be sufficient to meet about 10 percent of the demand. U.K. will become a net importer of oil by 2000 and Canada will be in a position to supply only 3 percent of the demand. This implies that almost 47 percent of the demand will have to be met by imports from the Arab-OPEC countries.

9. Policy Options to Reduce Vulnerability

While the lower price of oil and the increasing demand in the developing countries poses a threat to the long-term security of oil supply to the United States, they also present an opportunity to reduce the vulnerability to supply disruptions in the future.

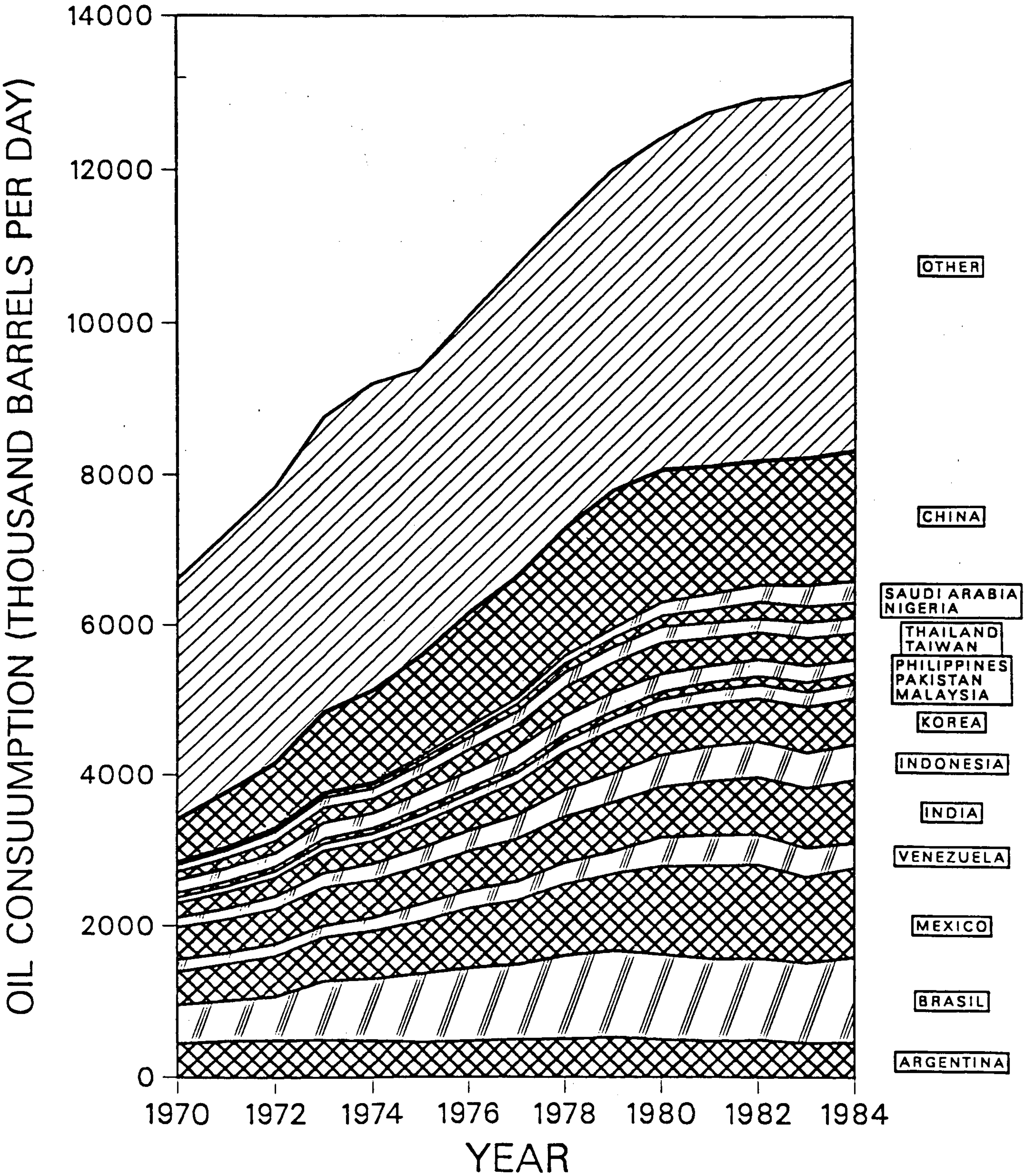
Conservation: While the amount of oil used by the developing countries constitutes a small fraction of the total oil demand, its use is highly inefficient in both the oil importing and exporting LDCs. This inefficiency in use of oil in LDCs could be substantially improved through the use of U.S. technology and management knowhow.

Exploration: The LDCs are far less explored for oil and natural gas than the U.S. Industry estimates suggest that U.S. companies are now spending 30 percent less on oil exploration and development abroad. Increasing exploration is important to increase reserves worldwide and reduce pressure on the oil market from rising demand in these countries.

Alternative Transport Fuels: The forecast of oil demand shows the greatest uncertainty in the demand for fuels in the transport sector. The United States is in a position to take the lead in introducing new technology in vehicles capable of using alternate fuels such as methanol. Such technology would also help reduce the demand for transportation fuels in the LDCs.

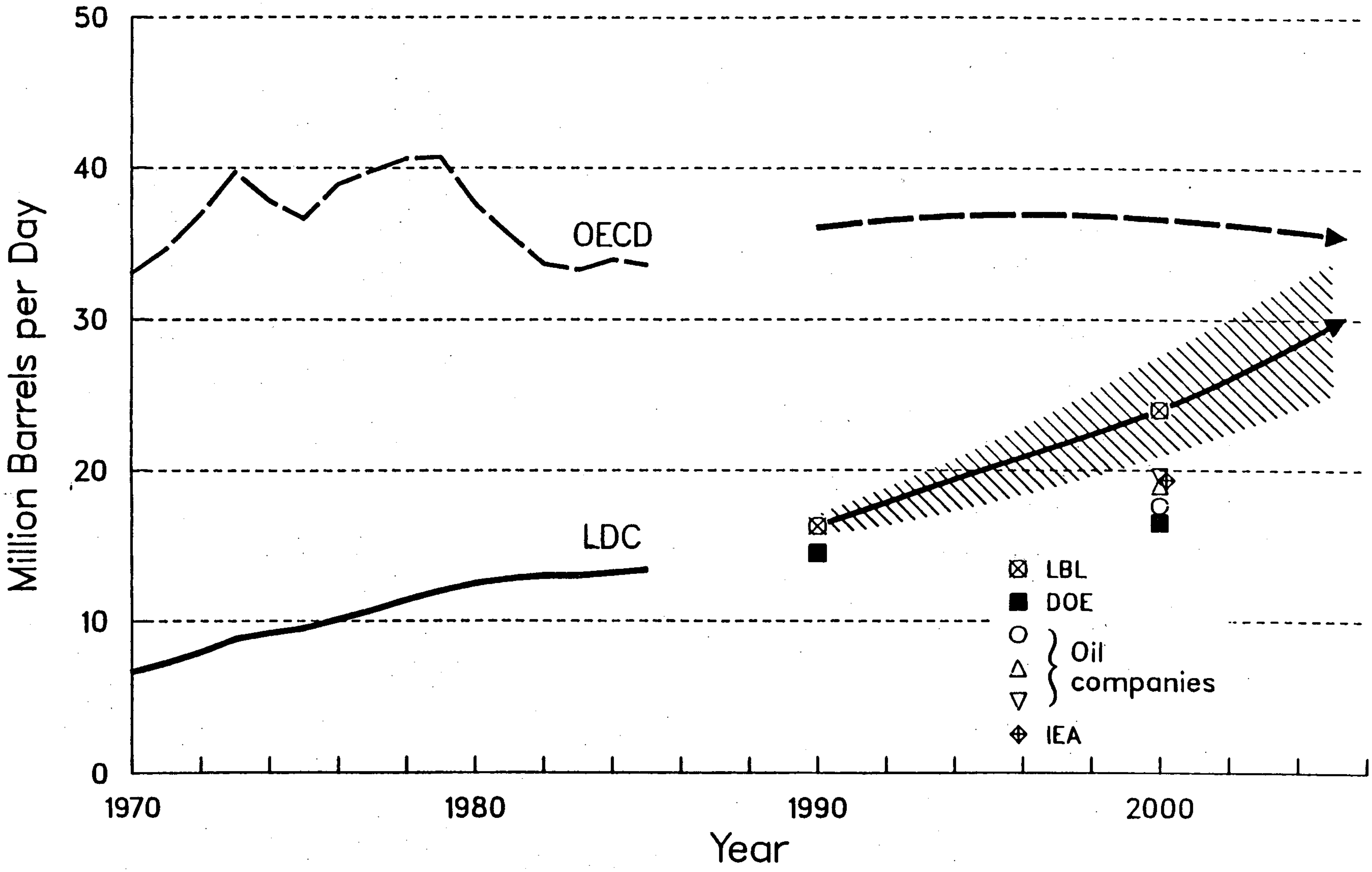
FIGURE 1

LDC OIL CONSUMPTION



SOURCE: *International Energy Studies, Lawrence Berkeley Laboratory*

Forecast of Oil Demand



SOURCE: *International Energy Studies, Lawrence Berkeley Laboratory*

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FIGURE 3

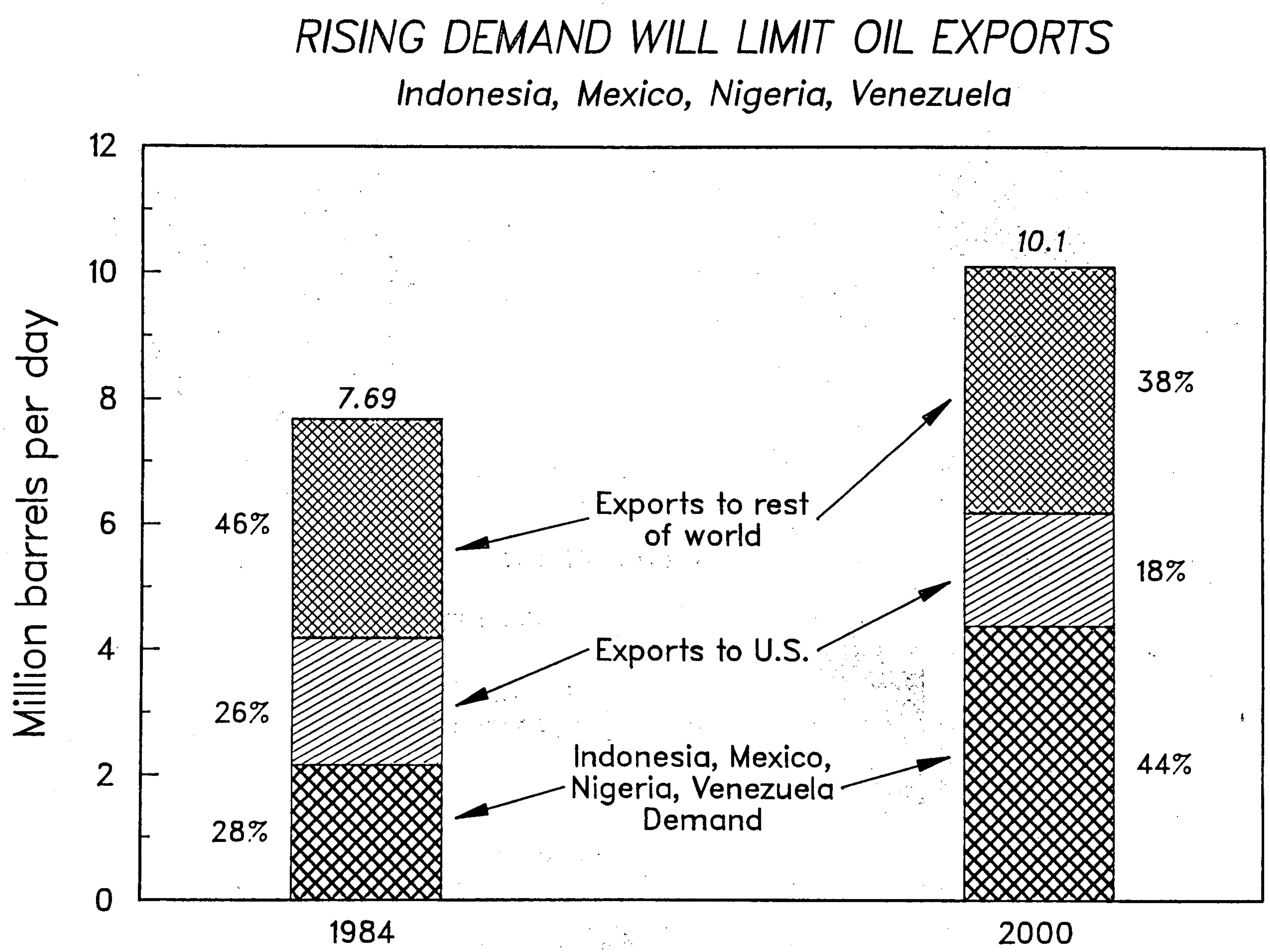

FIGURE 4

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RELIANCE ON OPEC OIL WILL INCREASE SIX FOLD

U.S. OIL SUPPLY

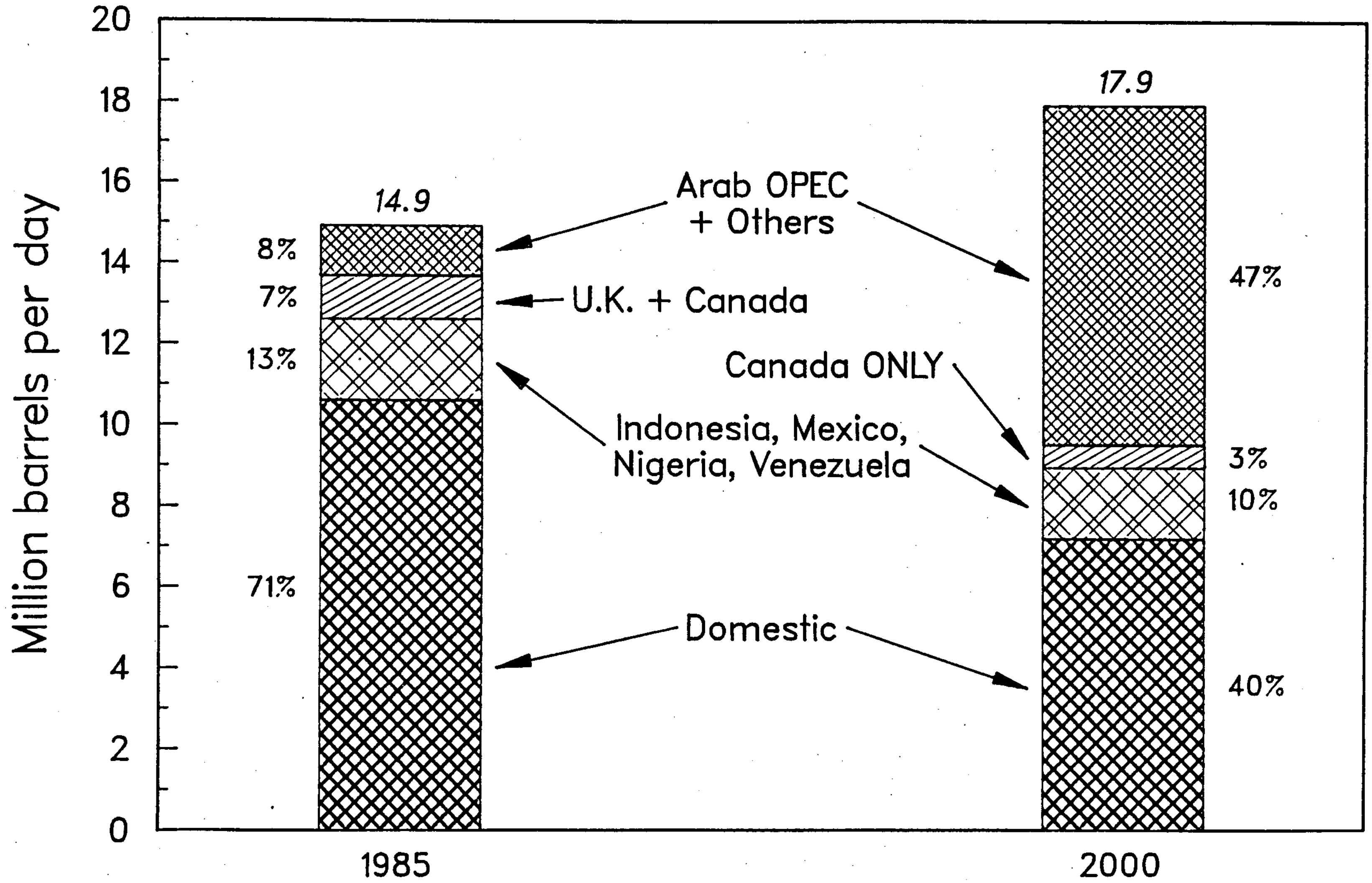

Figure 5

XCG 8611-12269

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