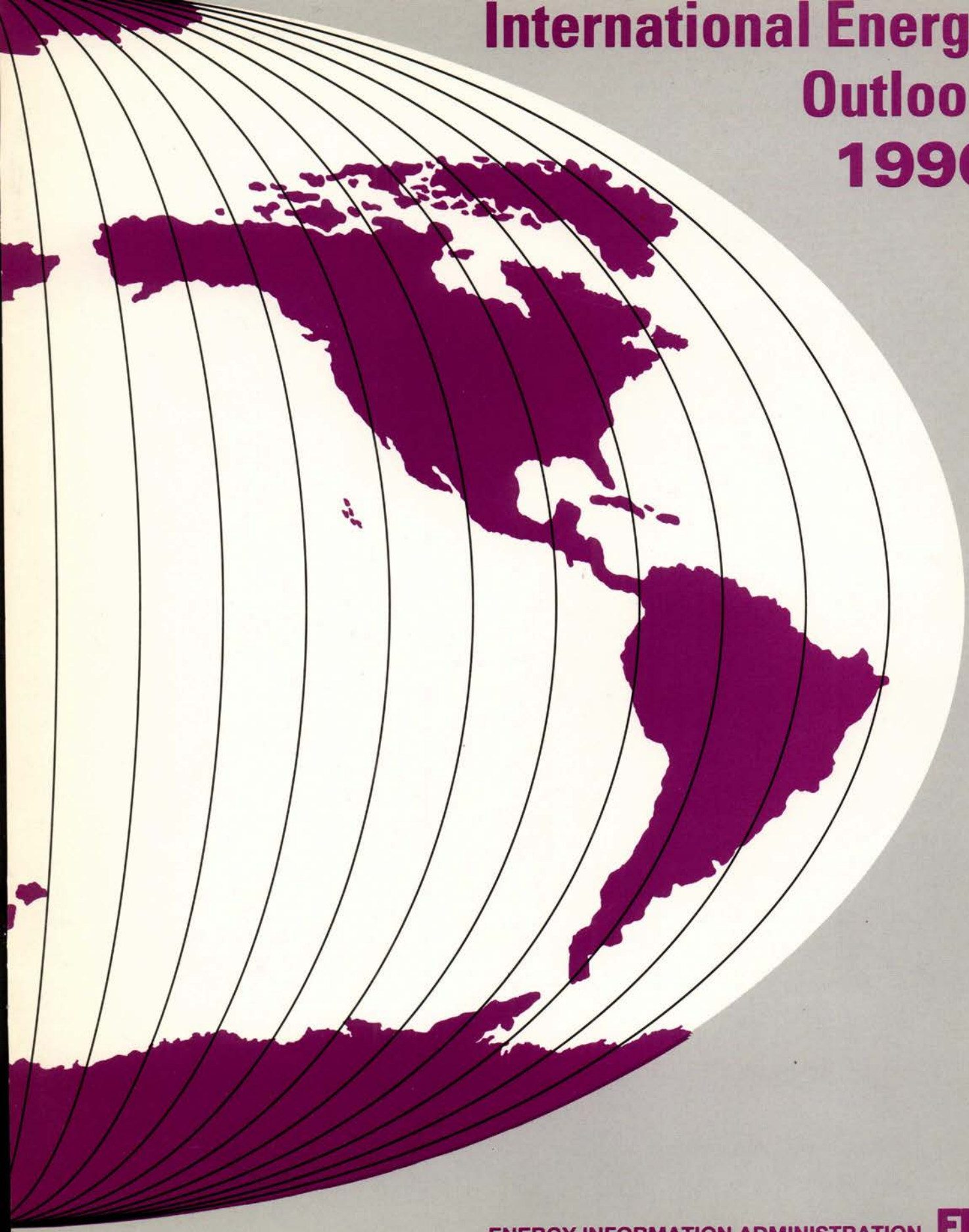
International Energy Outlook 1990



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Preface

This report presents the current Energy Information Administration (EIA) assessment of the long-term outlook for international energy markets. This report is provided, as are other EIA reports, as a statistical service for use by managers and international energy analysts and not as a government energy plan. Current United States Government policies and foreign government policies are assumed to hold over the projection interval, which extends to the year 2010.

This report emphasizes oil market developments, particularly future world oil prices and oil production potential. This emphasis in no way minimizes the importance of other energy markets; moreover, the analysis recognizes that the development of alternative energy sources impacts directly on the world oil market. The world oil price projections developed in this international setting are, in turn, used as assumptions for analyses of the United States domestic energy market provided in EIA's *Annual Energy Outlook 1990.* Since the United States energy market affects and is affected by the international market, the methodology incorporates this interaction to the extent possible. The domestic energy projections shown in this report are the same as those contained in the *Annual Energy Outlook 1990.* Projections in this report are also consistent with those published in EIA's October 1989 *Short-Term Energy Outlook.* Sources providing more detailed discussions on the United States domestic markets and other subjects discussed in this report are referenced in Appendix D.

Several major assumptions determine, in large part, the resulting projections. Much professional judgment, based on recent trends, reviews of many country reports, and projections made by other energy forecasters, went into developing the forecast assumptions and into projecting the overall energy balances. The major assumptions made include estimates of the energy intensity of economic activity, oil production capacities, and the rate of incremental energy requirements met by alternatives to oil. The projections call for fairly smooth patterns of growth between now and the year 2010. However, since 1973, the world energy market has been characterized by major swings in most market indicators. The uncertainty of the projections is conveyed by the projection ranges. Point estimates are deemphasized.

Projected uncertainty ranges for world oil prices and energy consumption are derived by altering mid-case assumptions concerning economic growth, energy demands, and energy supplies. First, the impacts of the variations in assumptions are estimated individually. Next, a combined range of uncertainty is determined and consists of the square root of the sum of the squared individual impacts. The result is a range that is greater than any single impact but less than the impact of all changes taken simultaneously.

Projections for the United States are from the *Annual Energy Outlook 1990* and were prepared with a set of spreadsheet models of the United States energy economy. Projections of foreign oil production and consumption, and prices of world oil were prepared using the Oil Market Simulation (OMS) model. Projections of foreign nuclear power consumption are based on capacity figures in Energy Information Administration, *Commercial Nuclear Power 1989: Prospects for the United States and the World,* DOE/EIA-0438(89) (Washington, DC, 1989). Inquiries concerning the availability and documentation of these models should be directed to EIA's National Energy Information Center (202/586-8800).

Projections of foreign gross domestic product (GDP) are derived by multiplying population as projected in United Nations, *World Population Prospects 1988* (New York, 1989) times GDP/per capita ratios used for the nuclear projections presented in *Commercial Nuclear Power 1989.* Assumptions about total energy requirements of projected economic growth and about marginal changes in the makeup of that total (fuel shares) are used to complete the projections in this report.

Certain country groupings are used frequently in the report. The Centrally Planned Economies (CPEs) group includes Albania, Bulgaria, Cambodia, China, Cuba, Czechoslovakia, East Germany, Hungary, Laos, Mongolia, North Korea, Poland, Romania, the Soviet Union, Vietnam, and Yugoslavia. The Organization for Economic Cooperation and Development (OECD) includes Australia, Austria, Belgium, Canada, Denmark, Finland, France, West Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States. The Organization of Petroleum Exporting Countries (OPEC) includes Algeria, Ecuador, Gabon, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, the United Arab Emirates, and Venezuela.

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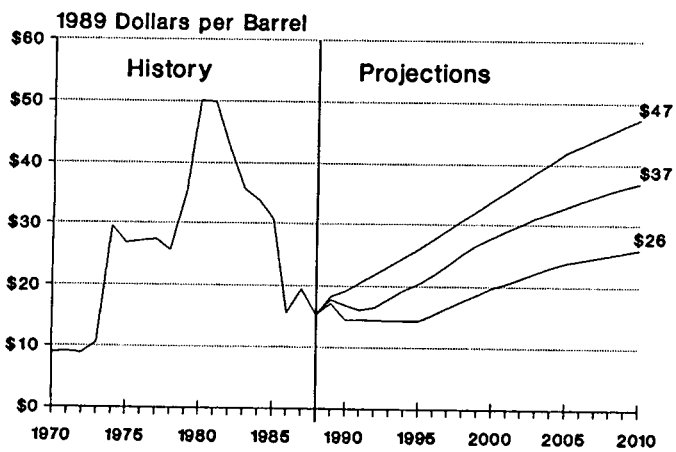
Executive Summary

The decade of the 1990's begins with prospects for major political and economic changes in parts of the world currently described as the Centrally Planned Economies (CPEs). Together, the CPEs consume about one-third of the world's total energy. These countries control large reserves of oil, natural gas, and coal. The development and use of these energy resources will have important implications for the future of both the CPEs and the Market Economies, particularly in the area of international trade. CPE exports of oil are likely to become less important to the Market Economies, while their exports of natural gas should become more important. Exports of these fossil fuels will come primarily from the Soviet Union. Coal is the dominant energy resource in China providing over three-quarters of the country's total energy requirements, and expected to continue to do so over the next 20 years. China holds the third largest total recoverable reserves of coal next to the United States and the Soviet Union.

Figure ES1. Range of World Oil Prices, 1970-2010

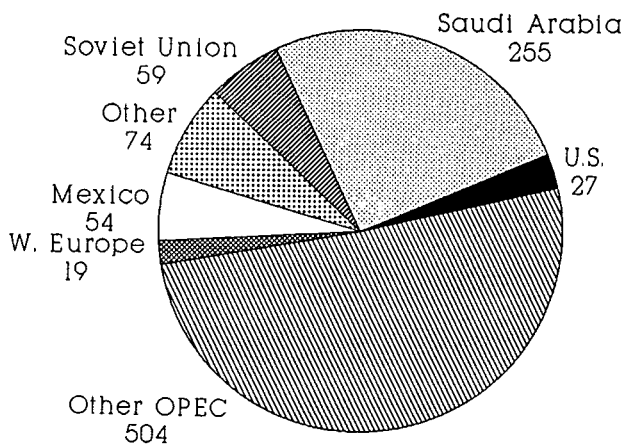


Source: See Appendix D.

Net oil exports from the CPEs to the Market Economies are projected to decline from just over 2 million barrels per day in 1990 to about 1.5 million barrels per day by 2000, and then to cease by the year 2010. The decline in oil exports parallels a decline in oil supplies from countries other than those belonging to the Organization of Petroleum Exporting Countries (OPEC). Non-OPEC oil production in the Market Economies is expected to peak at about 28 million barrels per day in the next few years and to decline steadily thereafter, to between 24 and 26 million barrels per day by the year 2010.

In 1988, OPEC produced one-third of all oil consumed in the world, about 22 million barrels per day. Depending upon growth in oil demand, OPEC production could range between 28 and 40 million barrels per day by the year 2010. The most likely range for world oil prices in 2000 is $20 to $34 per barrel, compared with $18 per barrel in 1989. By 2010, the range is $26 to $47 per barrel, all prices in constant 1989 dollars (Figure ES1).

Figure ES2. World Oil Reserves, January 1, 1989 (Billion Barrels)



Source: See Appendix D.

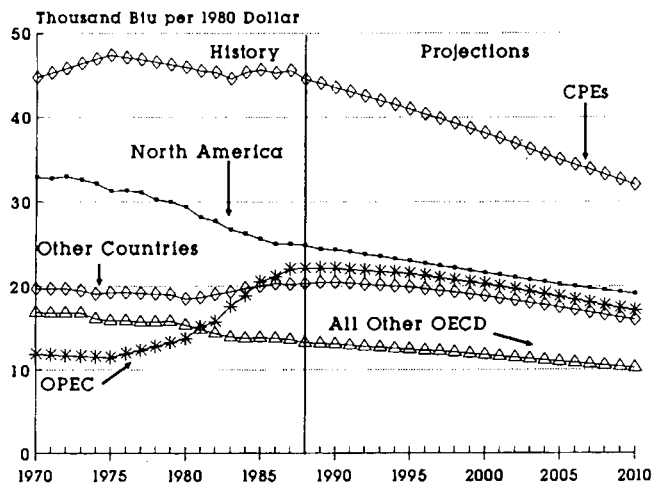
OPEC accounts for about 3 of every 4 barrels of the world's total reserves, which have been estimated in excess of 990 billion barrels (Figure ES2). Increased production will not occur uniformly among all OPEC countries, however, but will come primarily from an "inner core" of five Persian Gulf countries with vast, low-cost oil resources: Saudi Arabia, Kuwait, Iraq, Iran, and the United Arab Emirates. Five countries--China, Mexico, Norway, the United States, and the Soviet Union--hold the vast majority of non-OPEC oil reserves.

Oil consumption in the Market Economies should continue to grow over the projection period, from about 53 million barrels per day in 1990 to between 53 and 65

million barrels per day by 2010. Most of the increase in oil consumption among the industrial countries belonging to the Organization for Economic Cooperation and Development (OECD) is expected to occur in the United States. The major producer of oil among the OECD countries, the United States, will supplement domestic production with increased levels of oil imports.

Additional growth in oil consumption in the Market Economies is expected among the less developed countries (LDCs). Within the LDCs, growth in oil consumption among the OPEC countries will be limited by demand factors, primarily the completion of petrochemical projects that use oil inputs. Oil consumption and production among the remaining LDCs are estimated to be just under 11 million barrels per day in 1990. However, while oil production is projected to peak at this general level, oil consumption should continue to grow about 1 percent per year through 2010. Oil consumption will fall among the CPEs, as oil reserves decline.

Figure ES3. Energy Consumption/GDP Ratio, 1970-2010

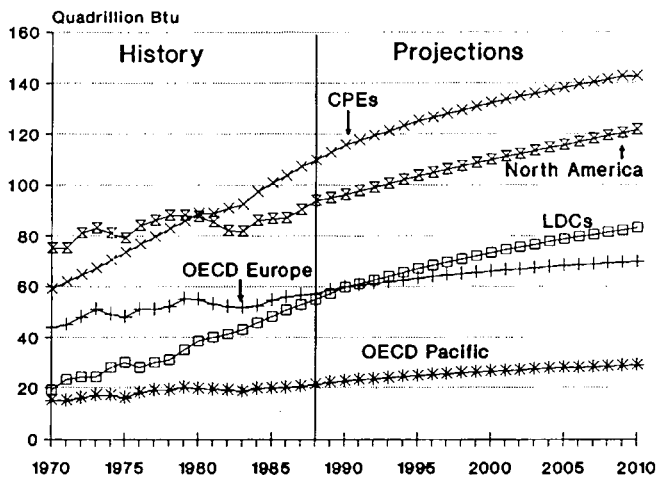


Source: See Appendix D.

Also contributing to oil consumption patterns among the major regions of the world are assumptions about economic growth as measured by gross domestic product, (GDP). Starting from a lower base, economic activity is assumed to grow most rapidly in the LDCs as a group, at an average rate close to 3 percent per year from now through 2010. The annual growth rates for the OECD and CPE countries over this period should be closer to 2.2 percent and 2.6 percent, respectively. Economic growth worldwide is assumed to average around 2.4 percent per year. As has been the case since the oil-price shocks of the 1970's and subsequent efforts to improve energy efficiency and conservation, total world energy consumption is not expected to grow as fast as total economic activity (Figure ES3). World energy consumption, estimated at about 337 quadrillion Btu in 1988, is projected to grow between 1 and 1.5 percent per year, to a range between 427 and 467 quadrillion Btu by 2010. As with economic growth, energy consumption is projected to grow most rapidly among the LDCs, ranging between 1.5 and 2.3 percent per year from 1988 to 2010 (Figure ES4).

There are several reasons for relatively rapid growth in energy consumption among the LDCs. "Non-commercial" energy resources such as firewood, excluded from the forecasts presented here, are rapidly being replaced by "commercial" energy sources, such as electricity and kerosene, due to both rising incomes and increasing urbanization. The penetration of energy-using equipment, such as refrigerators, motor scooters, and automobiles, while low in many developing countries, is rising rapidly in LDCs. India, Brazil, Mexico, Korea, Singapore, Taiwan, and China are rapidly developing energy-intensive basic industries such as steel and petrochemical plants. These basic industries produce the inputs to supply growing markets for energy-using equipment.

Figure ES4. World Energy Consumption by Region, 1970-2010



Source: See Appendix D.

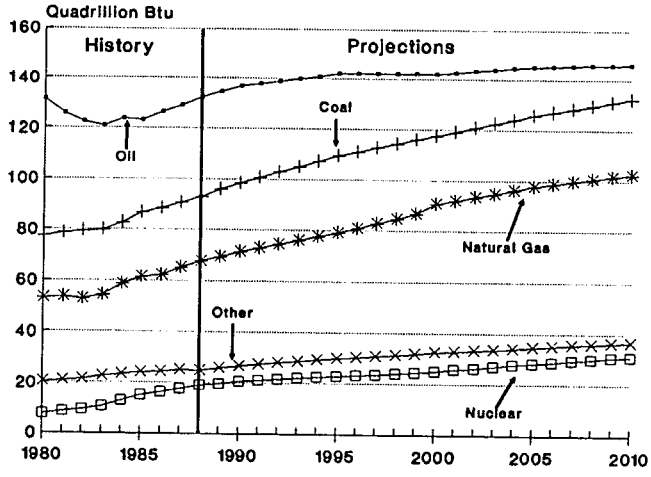
There are several reasons why energy demand should increase more slowly among the OECD countries than among the LDCs. The OECD countries are the most capable, technically and financially, of implementing energy efficiency measures. Accumulation of energy-using equipment, such as refrigerators and automobiles, is much nearer to saturation. Thus, future increases in consumption may be more responsive to household formation and population growth than to general economic growth. In addition, the composition of economic output in the OECD countries will probably continue to shift from energy-intensive basic industries to

less energy-using services and information-technology industries.

Energy efficiency in the CPEs is expected to improve rapidly over the next 20 years, given the apparent inefficiency with which inputs, including energy, are currently used. Market-oriented reforms, which might induce rapid economic growth in the CPEs, could also induce large increases in the efficiency of energy consumption, thus reducing the overall rate of growth in energy use (Figure ES4).

Oil will continue to be the single most important source of energy in the world over the next 20 years, but its relative importance will continue to decline, from 45 percent of the total in 1980 to about 39 percent in 1988 to about 32 percent of the total by 2010 (Figure ES5). All other major fuels are expected to grow in relative importance. As with oil, natural gas resources are very unevenly distributed, with major reserves located in the Soviet Union and the Persian Gulf. Natural gas is favored because it can reduce dependence on oil and reduce the environmental problems associated with other fossil fuels, particularly coal. Coal consumption is expected to grow, primarily to help meet increasing demands for electricity. Hydroelectric and nuclear power will also be used to meet these demands. However, growth of these energy sources will be highly dependent on the approaches and technologies used to reduce the environmental costs associated with their use.

Figure ES5. World Energy Consumption by Type, 1980-2010



Source: See Appendix D.

World Oil Prices

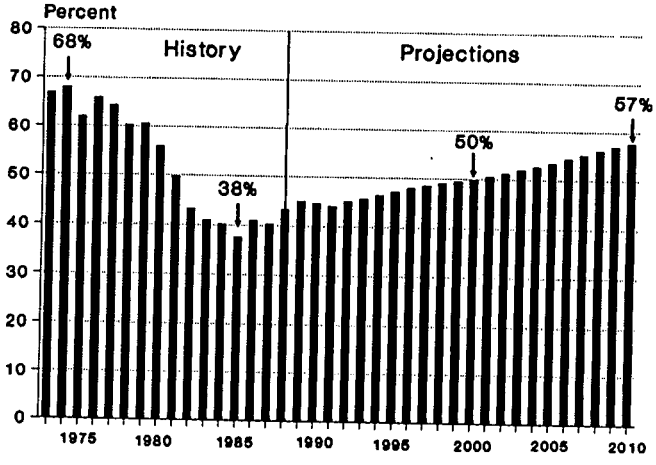
For most of the past decade, world oil prices have fallen as the market share held by the Organization of Petroleum Exporting Countries (OPEC) has declined (Figure 1). The price increases of the 1970's caused complex interactions in the world oil markets, including increases in energy efficiency, decreases in consumption, and increases in non-OPEC supplies that resulted in decreased market share and increased excess production capacity for OPEC. The events of the past few years have demonstrated that attempts by OPEC to maintain a marker price by acting as the swing producer and restricting output can result in losses in both market share and revenues (Figure 2). Despite its attempts at restricting output during the early 1980's in response to falling demand, OPEC was unable to maintain prices. As OPEC cut back supply, its excess production capacity increased and its capacity utilization decreased. Prices continued to fall while OPEC lost market share, resulting in decreased oil revenues. Historically, it has been easier for OPEC to influence prices when the demand for its oil has been high. Since the price collapse in 1986, many OPEC countries have pushed to regain lost revenues by trying to maintain acceptable market shares. OPEC has steadily increased both market share and nominal revenues since 1986, while abandoning attempts at maintaining an official marker price. In this context, OPEC cannot always be viewed as a coherent entity; i.e., some individual member countries are more adamant than others about the necessity for higher oil prices.

Near-Term Influences

Against this backdrop, 1989 could have been much like 1988, when OPEC production rose sharply and prices were at their lowest levels (adjusted for inflation) since the 1986 price collapse (Table A1). However, world oil prices (as measured by the imported refiner's acquisition cost) rose by over $3 per barrel in 1989, unadjusted for inflation. This rise, which followed a $3.50-drop in 1988, surprised many observers because it occurred despite an increase in OPEC production (all liquids) of 1.4 million barrels per day. Several factors enabled OPEC to increase its market share without causing world oil prices to drop. The primary reason was stronger-than-anticipated demand for petroleum products by the Market Economies. Demand increased by 1.2 million barrels per day, or 2.4 percent, from the 1988 rate. At this rate, demand was only 310,000 barrels per day below the record high set in 1979. Another major factor was the unexpected decline in the United Kingdom's production, which led to a 390,000 barrel per day drop in non-OPEC production, only the second such decline since 1975.

More OPEC production discipline will be required in 1990 than in 1989 to avoid price declines. The drop in production in the United Kingdom was the result of a series of accidents which is not expected to be repeated in 1990, while non-OPEC production in the Market Economies is expected to increase by 630,000 barrels per day in 1990. Demand in the Market Economies is expected to continue to increase in 1990 at a slower, 2.1 percent rate. As a result, OPEC may have to hold production (all liquids) to 23.7 million barrels per day in 1990, an increase of only 240,000 barrels per day from the 1989 rate. This could prove difficult to attain.

Figure 1. OPEC Oil Production as a Percentage of Oil Demand in the Market Economies, 1973-2010

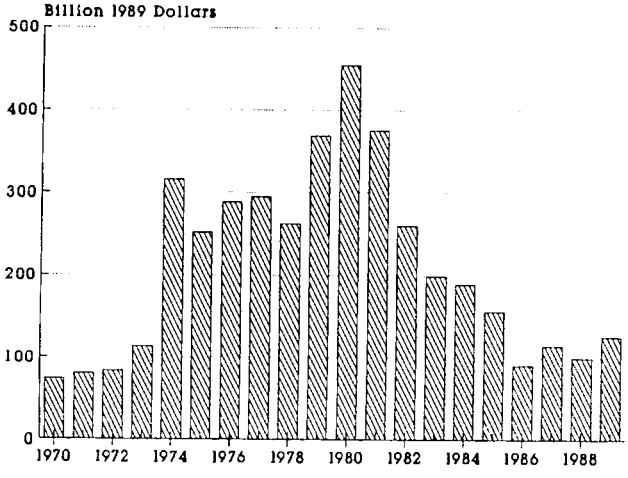


Source: See Appendix D.

OPEC met in November in Vienna, and reached a new agreement that set the crude oil production ceiling at about 22.1 million barrels per day for the first half of 1990 and incorporated Kuwait's claim to a higher market share within OPEC. The demands of the United Arab Emirates (UAE) were not satisfied, however, and it is expected that the UAE will continue to produce well in excess of its nominal quota level. Some other OPEC countries will produce below their quota levels because the quotas exceed their production capacity. The net result is that OPEC does not expect its crude oil production to be more than about 500,000 barrels per day higher than the production ceiling in early 1990. However, the estimated call on OPEC crude oil for 1990

is expected to be at or below the production ceiling level. This suggests that oil prices could fall in 1990, particularly in the first half of the year, when the demand for OPEC oil is expected to be at seasonal lows. Prices may not slide if, as some Persian Gulf oil ministers believe, declining output in the United States and the Soviet Union, and continued strong growth in demand result in a higher demand for OPEC oil.

Figure 2. Total OPEC Oil Export Revenues, 1970-1989



Source: See Appendix D.

Longer Term Trends

Beyond the mid-1990's, oil prices are expected to rise. Non-OPEC production is expected to peak and level off worldwide, while production in the United States will continue to decline (Table A2). Many analysts have been surprised at the strong level of oil demand during the past year or two, and believe that it is a lagged response to the low prices which have prevailed since the 1986 price collapse. Demand in the Market Economies is expected to keep growing in response to the relatively low world oil prices expected over the next several years. Even with a firming of world oil prices over the next few years, prices would still be relatively low compared to historical levels since the early 1970's.

World oil prices have fluctuated over the past 2 decades, with price increases resulting in cutbacks in demand, and steady or declining prices encouraging consumption and economic growth. Based on past experience with price swings and the recent strong increases in demand, there is reason to believe that the relatively low prices expected until the mid-1990's will result in demand increases that could cause prices to rise yet again. This rise in world oil prices is projected to slow after 2000 in response to demand reductions brought about by post-1995 price increases.

The degree to which oil prices will rise depends largely on OPEC behavior. Future OPEC production decisions will be determined by a variety of factors. Market forces determine the overall bounds within which OPEC can influence world oil markets, but within these bounds, market share and revenue goals, as well as political and security considerations, will exert great influence on OPEC production and capacity decisions. The most likely course is that pressures to earn more revenues, along with the expected increase in demand for OPEC oil, will continue to encourage OPEC member nations to expand their production capacities in the future. The market strategies eventually chosen by OPEC will determine the rate of capacity expansion, and whether this expansion will keep up with demand growth. Continued capacity expansion will result in moderate increases in oil prices, which would be consistent with OPEC's wish to discourage the development of alternative technologies and synthetic fuels that could reduce the long-term demand for OPEC oil.

There has been a tendency in previous oil price projections to assume that whatever price trends prevailed when the projections were being made would continue indefinitely. During the late 1970's, for instance, prices were increasing, and price projections for the future duly showed continued increases. Similarly, many projections made after the price collapse of 1986 showed continued low prices. The projections made in this *Outlook* incorporate the tendency for prices to fluctuate within a range. Following past fluctuations, it is believed that price swings outside this range are unsustainable. While prices may go above this range, it is believed that this will discourage demand and encourage the development of new supplies, thus driving prices back into this range. Similarly, prices below this range have the opposite effect.

The high- and low-price ranges presented in Figure ES1 and Table A1 are not associated with a single high or single low world balance of oil supply and demand as is the mid case (Table A2). Instead, the ranges represent the combined uncertainity caused by events such as unexpected (whether lower or higher) growth in demand, non-OPEC supplies, and OPEC production capacity. The price range for the year 2010, between $26 and $47 per barrel in 1989 dollars, roughly encompasses the range of prices that prevailed between 1974 and 1985 (Figure ES1). Although the mid case is presented for analytical convenience, the range of forecasts, rather than a particular point estimate, envelops the most likely outcome.

Major Assumptions

Economic Growth

As in the past, economic growth will be a major factor in determining the size and makeup of future energy markets. Increased economic activity projected worldwide results in increased use of all energy sources. Economic growth and energy consumption are expected to grow faster in the developing countries than in the industrialized countries of the Organization for Economic Cooperation and Development (OECD) or than in the Centrally Planned Economies (CPEs). Economic activity is expected to increase most rapidly among the newly industrialized countries of Asia.

Economic growth and, therefore, energy consumption may grow more rapidly in many developing countries because both are starting from a relatively low base. However, a major uncertainty concerning prospects for economic growth in several key developing countries arises from on going problems with foreign debt, particularly in Latin America. Potential energy sources such as nuclear and hydroelectric power require large outlays of capital. Given existing debt obligations, certain countries may not be able to attract needed capital, even if the energy resource potential exists.

In the OECD countries, economic growth is projected to be slightly higher in the North American countries--Canada and the United States, and in the Pacific countries--Japan, Australia, and New Zealand--than in the individual European countries. Under mid-case assumptions, economic growth in the North American and Pacific countries is projected to grow at or slightly above 2.5 percent per year between now and the year 2000 and slightly below 2.5 percent per year between 2000 and 2010. In European countries, the economy is projected to grow at or slightly below 2 percent per year from now through 2010; growth in the developing countries is projected at an average rate of about 3 percent per year over the next 20 years; growth in the Centrally Planned Economies is projected at about the same rate as the developing countries through 2000 and at about the same rate as the Market Economies taken together between 2000 and 2010 (Table B1).

Population Growth

Projected economic growth rates are generally lower than those of the past 20 years. Contributing to the lower rates are projections of declining population growth worldwide. Population determines the potential size of the labor force, and, over the longer term, labor force is a major determinant of economic growth. In the United States, for example, population growth declined from about 1.1 percent per year between 1965 and 1970 to an estimated 0.8 percent per year between 1985 and 1990 and is projected by the United Nations to decline further over the next 20 years, down to about 0.5 percent per year by 2010. More precipitous declines in population growth are expected for Japan and Europe, including Eastern Europe. Though population growth in Japan was similar to that of the United States in the late 1960's, it is projected to decline to about 0.1 percent per year or less by the year 2010. Similarly, population growth in Europe is expected to average below 0.1 percent per year by 2010. Population growth patterns in the Soviet Union are expected to be similar to those in the United States.

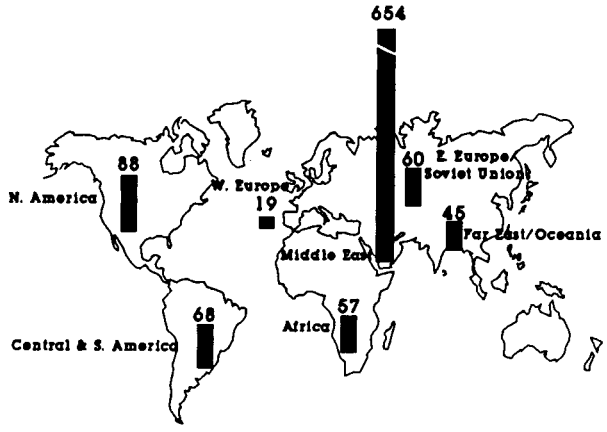
In contrast, the United Nations expects population growth in the developing countries to remain at high levels over the projection period. Growing at a rate of about 3 percent per year over the last 5 years, population growth in Africa could still exceed 2.5 percent per year by the year 2010. Population growth in Latin America and Southern Asia is expected to decline from just over 2 percent per year currently to about 1.5 percent per year by 2010. The most spectacular change in population growth trends is occurring in China. Growing at an annual rate of 2.6 percent between 1965 and 1970, the projected growth rate by 2010 is expected to be about 0.5 percent per year.

Productivity of the labor force is a second major determinant of economic growth over the longer term. Labor productivity can be enhanced through gains in training, capital formation, and technical innovation. The economic growth rates presented in Table B1 are based on the assumption that productivity, as measured by gross domestic product per capita, will continue to grow. For example, gross domestic product per capita is assumed to grow by just over 2 percent per year in Japan between 1990 and 2010 and just under 2 percent per year for the OECD countries, Canada, France, West Germany, and the United Kingdom. Productivity for the newly industrialized countries, South Korea and Taiwan, is assumed to increase by about 2 percent per year over the next 20 years and the Latin American countries, Brazil and Mexico, about 1.9 percent per year.

World Oil Resources

The prospects for future oil supply depend largely on the size and location of the reserves and resource base (Figure 3). In recent years, the development of oil reserves in non-OPEC countries has allowed their production to move ahead of the oil supply from OPEC. However, relative to OPEC, non-OPEC production prospects are more limited because of lower production capacity, reserve levels, and rates at which new oil is being found. Middle East OPEC countries dominate both the reserves and spare production capacity within OPEC.

Figure 3. World Crude Oil Reserves, January 1, 1989 (Billion Barrels)



Source: See Appendix D.

The projected future availability of crude oil is based primarily on current estimates of proved reserves and a continuation of present trends in exploration activity and the expansion of production capacity (Table B2). Estimates of world oil reserves and resources are made by engineers and geologists using various techniques to determine the likely amount of recoverable oil in an oil reservoir. Reserves in this report refer to "proved reserves," or oil that geological and engineering data demonstrate with reasonable certainty to be recoverable in future years from known reservoirs under existing economic and operating conditions. Resources refer to total resources, that is, identified reserves and undiscovered recoverable resources--oil that is not yet discovered but is thought to exist in a geologic setting that is favorable for oil extraction.

Because reserves and resources are based on estimation and judgment, it is important to recognize that there may be significant year-to-year shifts in the opinion of experts as to reserves and resources in a reservoir or country. Nevertheless, certain general statements can be made that are indicative of the future sources of petroleum supply.

- Recent evidence indicates that oil reserves in the world are in excess of 920 billion barrels and may exceed 990 billion barrels (Table B2). World resource estimates indicate that there is a 90 percent statistical probability that total resources including identified reserves and undiscovered recoverable resources are between 1,060 billion barrels and 1,720 billion barrels (U.S. Geological Survey).

- Crude oil reserves (as published in the *Oil and Gas Journal* and *World Oil)* increased between 1980 and 1988 despite real price declines and an average crude oil production level (including lease condensate) of between 55 and 56 million barrels per day, or about 180 billion barrels over the period.

- Almost two-thirds of the world's oil reserves are in the Middle East (virtually all in the Persian or Arabian Gulf). Countries in OPEC account for about 3 of every 4 barrels of total reserves.

- Five countries--China, Mexico, Norway, the United States, and the Soviet Union--hold the vast majority of non-OPEC oil reserves and resources in the world.

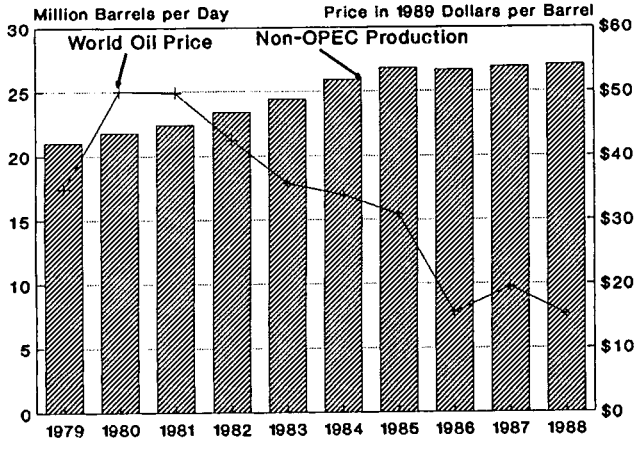
The search for oil in the Market Economies peaked in 1981. Exploratory activity is the initial step in finding additional reserves. There were over 6,200 active rigs in the Market Economies in December 1981--about 4,500 of these were in the United States. By the end of September 1989, there were about 2,300 active rigs in the Market Economies and about 955 in the United States. Thus, the decline of 3,500 active rigs in the United States accounted for about 90 percent of the overall drop in active rigs. The number of crews involved in seismic exploration also is an important indicator of petroleum exploration activity. According to the Society of Exploration Geophysicists, there were about 1,260 active seismic crews in the Market Economies and about 740 active crews in the United States at the peak in September 1981. Since then, the number of seismic crews in the Market Economies declined to about 360 crews in September 1989. The United States accounted for about 140 of the 360 active crews. Thus, the decline of 600 seismic crews in the United States accounted for about two-thirds of the decline in the number of active crews.

Oil Production Potential

Non-OPEC Production

In the past 10 years, oil production from non-OPEC countries among the Market Economies has been on the rise. In 1979, non-OPEC countries produced about 21 million barrels of oil per day. In 1988, non-OPEC oil production reached 27 million barrels per day (Table A2). This upward trend in oil production lagged behind trends in oil prices due to time delays caused by exploration and development activities (Figure 4). Oil prices peaked in 1980 and until recently have been declining. The price collapse in 1986 caused non-OPEC oil production to dip slightly in 1986 from its 1985 level, but production rose again in 1987 and 1988.

Figure 4. Non-OPEC Oil Production and Oil Prices, 1979-1988

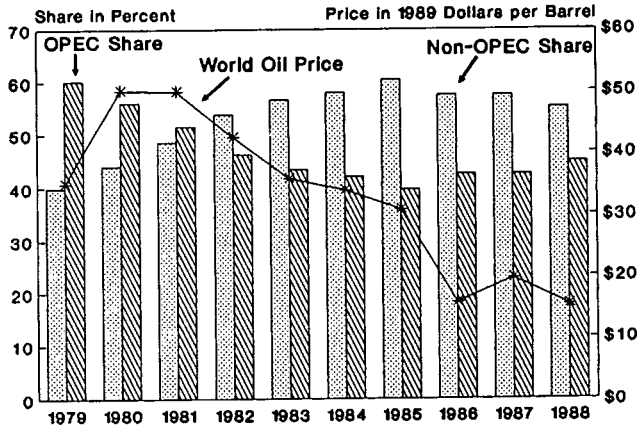


Source: See Appendix D.

Since the 1986 price collapse, mature oil producing countries such as the United States have had significant declines in production. There were, however, a number of countries that increased oil production significantly despite the price collapse. For example, Colombia increased oil production by more than 100,000 barrels per day in 1986. Norway and Malaysia also had significant gains in production. New producers also contributed to the increase in oil production. North Yemen, which produced only 10,000 barrels per day in 1986, produced more than 150,000 barrels per day by 1988. It is expected that non-OPEC oil production will continue to rise in the next few years.

Rising oil prices in the 1970's and high oil prices in the early 1980's stimulated exploration and development activities in non-OPEC countries. As a result, oil production and consequently the market share of non-OPEC countries have been increasing at the expense of OPEC's market share. In the Market Economies, non-OPEC oil production constituted 40 percent of total supply in 1979. This market share increased to about 60 percent in 1985 (Figure 5).

Figure 5. OPEC and Non-OPEC Production as a Share of Oil Demand in the Market Economies, 1979-1988



Source: See Appendix D.

OPEC's marketing strategy of the 1970's contributed to the increased market share of non-OPEC countries. In the 1970's and early 1980's, OPEC's strategy was to control supply in order to raise prices and total revenues. This marketing strategy worked very well for a few years until high oil prices stimulated oil production in non-OPEC countries and, at the same time, depressed oil demand. The long-term result of that strategy was a smaller market share for OPEC oil, lower oil prices, and, consequently, lower oil revenues.

In an attempt to regain market power, Saudi Arabia started the practice of net-back pricing--relating crude oil prices to refined product prices--to expand its sale of crude oil in late 1985. This expansion in oil supply contributed to the price collapse in 1986. Since then, non-OPEC oil producing countries have been losing market share despite the fact that total oil production from these countries is still increasing.

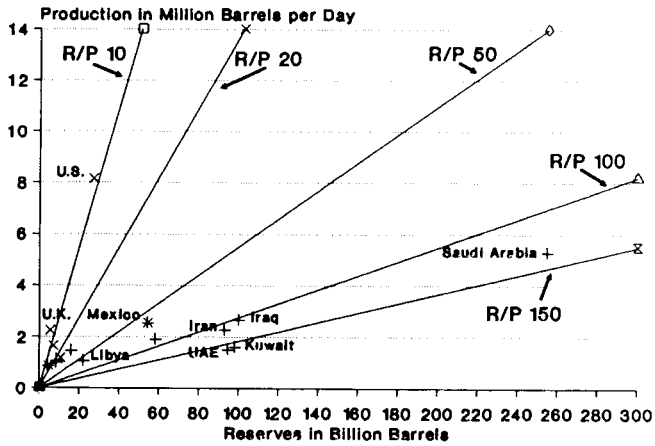
The ability to increase production is determined mainly by the financial resources available to these oil producing countries. Investment capital will determine the speed of development and the completion of infrastructure required to distribute the oil produced. In addition, government policy towards the development of existing proved oil reserves will also play an important role in bringing oil to production. For example, oil was discovered in North Yemen in 1984, but there was no significant production of oil until late 1987 and 1988. In this case, production of oil lagged behind discovery by about 3 years.

The development of proved reserves discovered in the early 1980's should allow the non-OPEC countries to increase production through the early 1990's. Countries such as Syria, Colombia, India, Brazil, the United Kingdom, Norway, North Yemen, and South Yemen all could increase oil production. These countries, as a whole, could more than offset the decline of oil production from other non-OPEC countries. But this increase in production is projected to peak in 1992 or 1993 and to decline thereafter, as most existing proved reserves are developed and new oil discoveries can not replace them--given low world oil prices and, consequently, lower exploration activities. Non-OPEC oil producers are very sensitive to oil prices. An extended decrease in the price of oil is likely to induce a decrease in oil production; an extended increase in the price of oil will likely stimulate non-OPEC oil production and even delay the inevitable decline in non-OPEC production by raising production capacity.

In addition to prices, another factor that affects production capacity is total resources: the sum of proved reserves and undiscovered resources. Capacity from proved reserves can be expanded by drilling more producing wells. Undiscovered recoverable resources could translate into production capacity if the price of crude oil is high enough to warrant a reasonable return on risky oil exploration activities. Total oil resources in the Market Economies were estimated to be in the range of 880 to 1,330 billion barrels. Total resources in OPEC were estimated to be in the range of 602 to 838 billion barrels (Table B2). The wide range of total resources reflects a distinct possibility that non-OPEC production capacity could also swing widely, depending on the price of oil and on government policies. Estimated production capacity for each country is based on the mean value of estimated undiscovered recoverable resources, and the allowed range is a 15-percent deviation from the mean value.

Other factors influencing production capacity are the technologies used to extract oil and the cost of secondary production and enhanced oil recovery. These elements can play an important role in changing the reserve-to-production ratio and future oil production capacity. Historical reserve-to-production ratios are good indicators for the potential increase in production capacities. These ratios show the development intensity of proved reserves. The estimated 1988 ratios for the United States, Canada, and United Kingdom are all less than 15; the ratios for Norway and Mexico are greater than 25. In contrast, the calculated reserve-to-production ratios for all the OPEC countries are greater than 15 and most of the ratios in the OPEC group are greater than 30. The ratio for Saudi Arabia exceeds 100 and that for Kuwait, exceeds 150 (Figure 6). Government policies toward exploration and development of natural resources and the terms stipulated for foreign joint ventures could also be very important determinants in both finding and producing oil.

Figure 6. Oil Production and Proved Reserves in the Market Economies



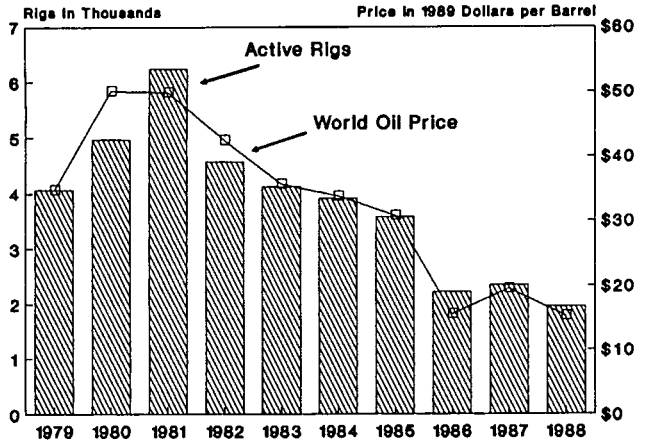
Source: See Appendix D.

The near-term increase in production potential in the non-OPEC countries comes mainly from the North Sea and from selected developing countries. In general, the cost of production in the United States and Canada is much higher than elsewhere due to the age and size of their oil fields. Given oil production technology, additional oil production from countries such as the United States, Canada, and the United Kingdom could come from more active exploration drilling activities, but would likely require very high oil prices to provide incentive for more intensive drilling and enhanced oil production processes.

Mexico, Norway, Brazil, North Yemen, and South Yemen are non-OPEC oil producers that can readily expand production capacity in the 1990's and thus affect world oil supplies. Mexico, which has large proved reserves, a high reserve-to-production ratio, and large undiscovered recoverable resources, could easily expand

its oil production capacity to a much higher level, provided the price of crude oil is high enough to stimulate production. Norway has much smaller proved reserves than Mexico. However, its production capacity could be increased with relative ease due to its high volume of undiscovered recoverable resources and a high reserve-to-production ratio. Brazil's recent new oil discovery could raise its oil production potential by another 400,000 to 700,000 barrels per day in the next few years. Both North Yemen and South Yemen are new producers. North Yemeni oil production in 1989 is expected to reach about 180,000 barrels per day. South Yemeni oil development is still at a very early stage, but production could exceed 100,000 barrels per day by 1991 and up to 250,000 barrels per day by 1995. The production trend for both North Yemen and South Yemen is upward until at least 1995.

Figure 7. Estimated Number of Active Rigs in the Market Economies, 1979-1988 (End of December)



Source: See Appendix D.

Although non-OPEC oil production in recent years did not decrease as the price of oil decreased, the total number of active rigs did reflect the price of oil. Figure 7 shows the relationship between world oil prices and the number of active rigs estimated as of December for each year from 1979 through 1988. Clearly, declining world oil prices have had a significant impact on the number of active rigs and, consequently, on drilling activities.

Current and projected low world oil prices should impact more on exploration drilling activities than on development drilling activities, since the cost of developing proved oil reserves and the rate of return on investments are relatively easy to estimate. As long as the economics of development permit, new production will be put on-line from proved reserves. The situation is quite different for exploration drilling activities, however, because the uncertainties and risks involved are much higher than they are in development drilling.

The beginning-of-year proved reserves for 1989 reported in the December 1989 *Oil and Gas Journal* showed an increase of almost 10 billion barrels over 1988 levels. But examination of new reserve additions indicates that most of the gains are the result of adjusting or confirming discoveries found over a period of years. For example, the new discovery in South Yemen reported in 1988 is the result of cumulative drilling efforts performed over the past several years. This type of new discovery becomes less likely as yearly drilling activities decrease due to low oil prices. Future non-OPEC production potential would be seriously reduced if the price of crude oil stays low.

OPEC Production

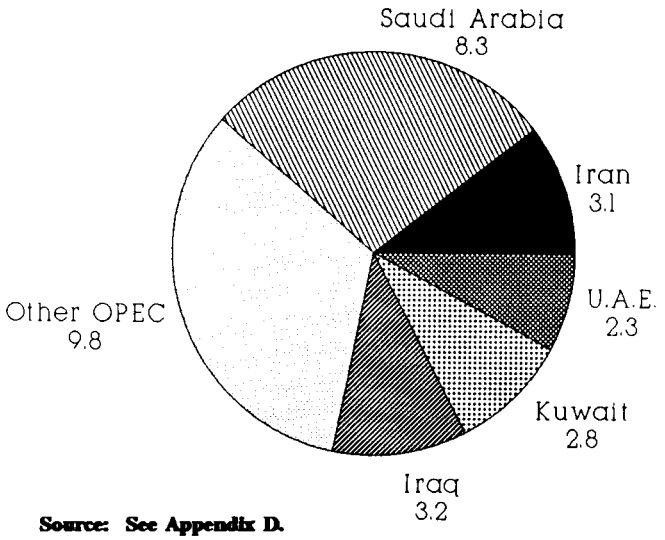
Estimated OPEC crude oil production in 1989 was over 21.5 million barrels per day, considerably higher than OPEC's self-imposed quotas of 18.5 million barrels per day for the first half of 1989, 19.5 million barrels per day for the third quarter, and 20.5 million barrels per day for the fourth quarter of the year. Production of total petroleum liquids (including natural gas liquids and condensates) reached 23.4 million barrels per day in 1989 (Table A2)--an increase of 1.4 million barrels per day over 1988 levels. Widespread predictions that this increase in OPEC production would force world oil prices lower in 1989 proved incorrect, however, as prices moved upward by over $3 per barrel (imported refiner's acquisition cost, unadjusted for inflation). By the time OPEC ministers met in Vienna in November, market analysts were in general agreement that the world oil market was relatively well balanced.

Even before OPEC convened in November, it was apparent that more OPEC production discipline would be required in 1990 than in 1989. In 1989, a higher-than-expected increase in oil consumption and an absolute decline in non-OPEC production enabled OPEC producers to increase their oil production, while at the same time commanding significantly higher prices.

In 1990, by contrast, the growth in oil consumption is expected to slow while non-OPEC oil production is expected to increase significantly. As a result, OPEC may have to hold its total production to about 23.7 million barrels per day, or only 240,000 barrels per day more than its estimated production for 1989, just to maintain current price levels. This level of production is fairly consistent with the new quotas agreed upon by OPEC when it met in November in Vienna. The November

meetings were considered a success, because Kuwait's demands for a higher market share were resolved and production from the Saudi-Kuwaiti Neutral Zone was explicitly incorporated into the quota. However, the continued failure to reach an agreement with the United Arab Emirates means that the UAE may continue to produce above its assigned production level. This excess production in the UAE will more than offset below-quota production in those OPEC countries that are relatively constrained by capacity.

Figure 8. OPEC Production Capacity, 1989 (Million Barrels per Day)

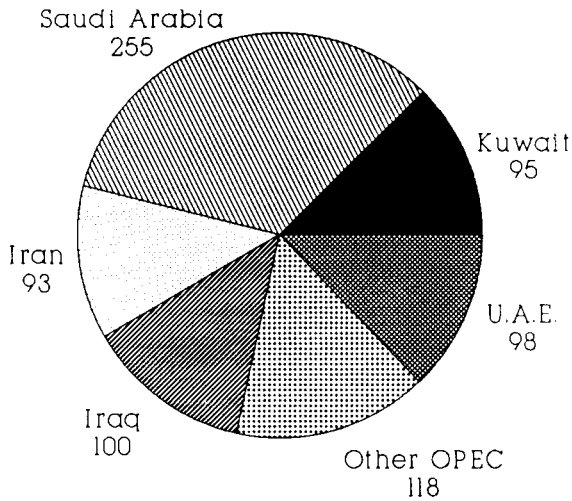


Source: See Appendix D.

The possibility that production quotas may be at least partly based on capacity (Figure 8) and reserves (Figure 9, Table B2) helps to explain the recent claims by some OPEC countries that their reserves are much higher than previously announced. The same reasoning has also given these countries additional incentives to increase production capacity. Saudi Arabia, for example, is aware that much of its influence within OPEC stems from its excess production capacity, and the implicit influence that this capacity gives Saudi Arabia over both the price of oil and the level of OPEC revenues. Saudi Arabia is therefore considering plans to increase its production capacity despite the fact that it already possesses substantial excess capacity. Total OPEC crude oil production capacity is currently estimated at 29.4 million barrels per day. Ranges through the year 2010 are presented in Table B3.

Events of the past few years have demonstrated to Saudi decisionmakers that attempts by OPEC to maintain a marker price by restricting output can result in losses both in market share (Figure 1) and in revenues (Figure 2). The failures of this strategy are highlighted by the nearly 80 percent decline in Saudi revenues in real terms from 1980 to 1986, despite Saudi Arabia's attempts to restrict its production levels in order to keep world oil prices from falling. This strategy failed primarily due to the decline in world oil demand and the increase in non-OPEC production (Figures 4 and 5). Since mid-1985, when Saudi Arabia abandoned its "swing producer" role (Figure 10), Saudi revenues have leveled off, at least in nominal terms. Saudi Arabia's current strategy appears oriented towards maintaining a certain level of income.

Figure 9. OPEC Proved Oil Reserves, January 1, 1989 (Billion Barrels)



Source: See Appendix D.

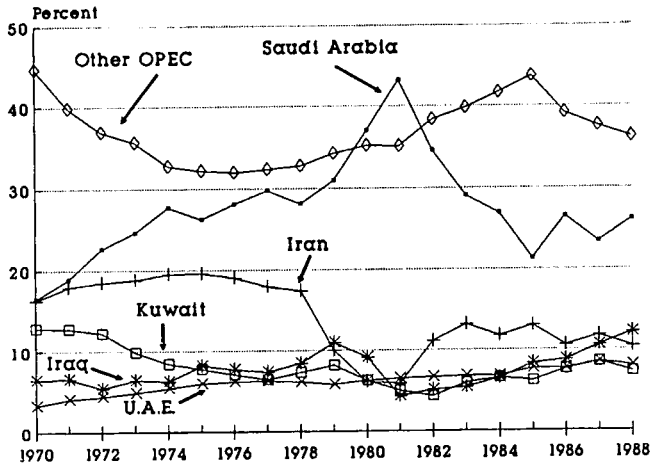
Future OPEC production decisions will be determined by a variety of factors. Market forces will determine the overall bounds within which OPEC can influence the world oil markets. Within these bounds, market share and revenue goals, as well as political and security considerations, will continue to exert a great deal of influence on OPEC production and capacity decisions.

The pressures to earn more revenues and to maintain market share, along with the expected increase in demand for OPEC oil, will continue in the future to encourage OPEC to expand its production capacity (Table B3, Figure 11). In addition, oil demand is expected to grow rapidly over the next 5 years, largely due to low world oil prices, and slow after that. World demand has already grown by a much faster rate than expected in 1989. Future growth in oil demand is expected in the United States and in the less developed countries despite increasing oil prices due to a continued expansion of economic activity in these regions.

Non-OPEC oil production should increase slowly over the next few years before leveling off. It is unlikely that this increase will be sufficient, however, to offset the increased call on OPEC oil caused by demand increases. An implied result of this scenario would appear to be an increase in real oil prices beginning in the next few

years. Whether this event will actually occur depends primarily on the rate at which OPEC increases its production capacity. Oil revenue and market share considerations in OPEC will go a long way towards determining the rate of this capacity expansion, and whether it will keep up with demand growth. A moderate OPEC pricing strategy would be consistent with OPEC's wish to discourage the development of alternative technologies and synthetic fuels that could reduce the long-term demand for OPEC oil. Although unconventional supplies from enhanced oil recovery, tar sands, and bitumen are being and will continue to be produced, no dramatic new sources of alternative supplies are expected to be produced in significant amounts before the year 2010.

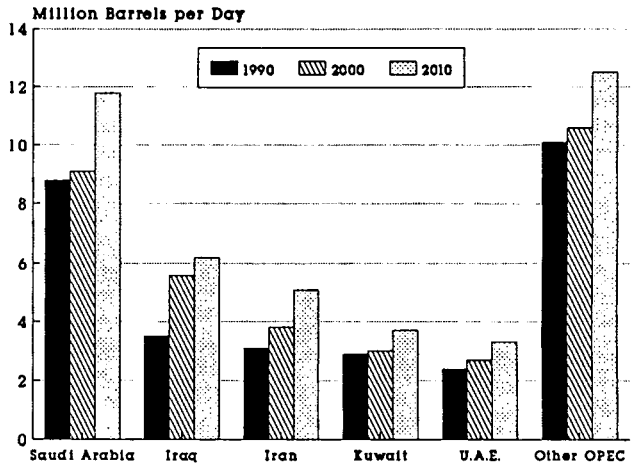
Figure 10. Market Share of Total OPEC Production, 1970-1988



Source: See Appendix D.

Beyond the year 2000, production capacity is expected to be limited by dwindling reserves in some countries. Within OPEC, small producers such as Gabon and Ecuador are expected to experience production declines as their reserves diminish. Other OPEC members, particularly the Persian Gulf countries, will be able to produce at current or possibly even increased rates for many years (Figure 11). Non-OPEC countries, on the other hand, are not expected to maintain production capacity above 1990 levels beyond the year 2000 (Table B3). Even with the increasingly sophisticated enhanced oil recovery methods and satellite field expansions that have helped to maintain non-OPEC oil production in the past, production in mature areas such as the United States and the North Sea will decline enough to result in a fall in non-OPEC capacity. The net result of this will be that world oil reserves and production capacity will increasingly be concentrated within a small group of producers, particularly the Persian Gulf producers.

Figure 11. OPEC Production Capacity, 1990-2010



Source: See Appendix D.

Petroleum Supply Vulnerability

Growing worldwide oil consumption and declining levels of domestic oil production make some regions of the world more dependent on foreign sources of oil. Persian Gulf countries supply the largest share of oil traded worldwide. The Persian Gulf countries are poised to regain the supply dominance they held in the 1970's, when they produced 40 to 45 percent of the oil consumed in the Market Economies. The high oil prices of the late 1970's and early 1980's led to greater non-OPEC production and less oil consumption, which by 1985 reduced the Persian Gulf share to 23 percent of Market Economies oil supplies.

Just as high oil prices diminished the role of Persian Gulf producers, lower oil prices since 1986 have re-established their role. Between 1985 and 1988, the Persian Gulf accounted for more than 90 percent--nearly 3.9 million barrels per day--of the increased oil production in the Market Economies. In 1989, about 30 percent of the oil supplies in the Market Economies are expected to come from Persian Gulf countries. Dependence on oil imports, particularly those from the Persian Gulf region, is rising:

- United States: Between 1985 and 1988, the percent of oil consumption met by oil imports rose from 27 to 38 percent. More importantly, the portion of net imports from the Persian Gulf rose from 7 to 23 percent. Persian Gulf imports averaged 1.5 million barrels per day in 1988, five times the quantity imported in 1985.

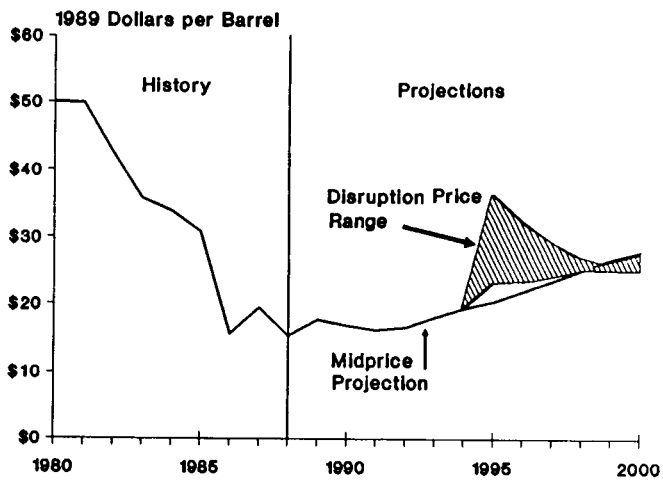
• Western Europe: This region imported 3.6 million barrels per day from the Persian Gulf in 1988, an increase of over 1 million barrels per day since 1985. Although net imports were about 65 percent of consumption in both years, Persian Gulf imports in 1988 met 29 percent of consumption (up 5.5 percent over 1985) and were 47 percent of net imports (up 8.8 percent over 1985).

• Japan: The Japanese are totally dependent on oil imports. Japan imported 2.7 million barrels per day from the Persian Gulf in 1988, only 0.16 million barrels per day more than in 1985. These imports represented about 58 percent of net imports, which was about 1 percent less than in 1985. Japan has attempted to diversify its suppliers, and product imports continue to displace crude imports.

To protect against rising vulnerability to a supply disruption, the consuming regions have built strategic stockpiles of crude oil. The United States' Strategic Petroleum Reserve (SPR) is the largest government-owned crude oil stockpile. Japan and West Germany are the only other countries to have sizeable government-owned stocks. Some European countries have government-controlled stocks, defined levels of stocks required of commercial stockholders and available for government use in an emergency. Together, there are close to 1 billion barrels of strategic stocks in the OECD. This level of stocks provides a substantial cushion against most potential short-term disruptions of oil supplies.

The growing concentration of remaining oil reserves and production in the Middle East (especially in the Persian Gulf) during the forecast period is not only likely to exert upward pressure on oil prices, but also could increase the potential for a serious disruption in oil supplies. Figure 12 illustrates what effects a closure of the Strait of Hormuz occurring in 1995 could have on world oil prices. This hypothetical disruption, although considered to be highly unlikely, could result in a net loss of about 9 million barrels per day, even after allowing for the use of excess production capacity and a surge in exports via alternative pipeline routes out of the Persian Gulf region. The hypothetical disruption begins on January 1, 1995, and lasts for 6 months. This example assumes that the United States responds to the disruption by drawing down the Strategic Petroleum Reserve at maximum rates at the same time that other countries in the Market Economies draw down their government-controlled stocks. Figure 12 shows that a hypothetical net disruption of 9 million barrels per day (only 1.3 to 4.3 million barrels per day after offsets such as drawdown of strategic stocks) could increase average annual oil prices by $4 to $20 per barrel, depending upon assumptions about commercial inventory behavior and the responsiveness of demand to price increases. The wide range of uncertainty reflects the substantially different ways in which the market may respond to a disruption in oil supplies. If suppliers and end users draw down commercial inventories in an effort to fill the supply gap, while consumers reduce energy use in response to higher prices, the economic effects of the disruption would be dampened and prices would tend toward the lower end of the range. Conversely, if consumption remains close to pre-disruption levels while commercial inventories are built up in anticipation of future prices increases (caused by uncertainty over the disruption's duration or magnitude), the economic effects of the disruption would be intensified and prices would tend toward the higher end of the range.

Figure 12. Range of World Oil Prices with Hypothetical Supply Disruption



Source: See Appendix D.

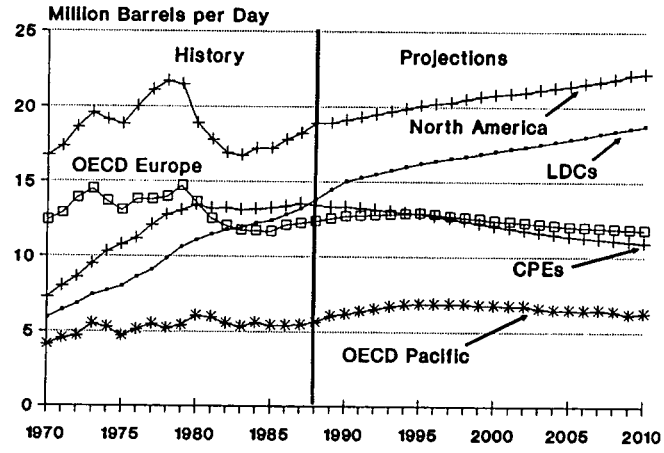
The aftermath of such a supply disruption is also highly uncertain. When oil supplies are restored (assumed in this example to occur in the third quarter of 1995), world oil prices could actually fall below the middle of the range. A cyclical pattern of price changes might then develop as a result of the continuing effects on oil demand in the post-disruption period, caused by past high prices and reduced economic activity. The actual price levels described are of less interest than this erratic pattern of price movements and its potential adverse effects on the world economy.

Oil Consumption Trends

World Oil Demand

The demand for oil is expected to increase in response to economic growth worldwide and in response to world oil price changes. Oil consumption is expected to increase more rapidly in the early 1990's as prices remain relatively low and increase more slowly in the late 1990's and beyond, as prices begin to rise and as economic growth begins to moderate (Figure 13). As in the past, conservation efforts, efficiency gains, and government policies will also influence oil consumption trends, as will the success to which alternative motor fuels, such as gasohol, can be developed.

Figure 13. World Oil Consumption, 1970-2010



Source: See Appendix D.

Oil consumption in the Market Economies, which accounts for about 4 out of every 5 barrels of oil consumed, is the major influence on oil consumption trends in the world as a whole. Oil consumption in the CPEs is projected to decline steadily over the entire projection period as oil reserves decline.

Oil consumption in the Market Economies is projected to grow steadily over the next 20 years, but this growth could approach zero by the year 2010 in the OECD countries taken as a group. Virtually all of the growth in oil consumption in OECD countries beyond 2000 is projected to occur in the United States, and much of that growth is in motor gasoline consumption. The United States has greater sources of domestic supplies from which to draw than do other OECD countries, and greater distances to be traveled for business, commerce, and recreation. These factors help to explain the varied oil consumption trends projected for the individual OECD countries.

Oil consumption is expected to grow most rapidly in the developing countries (Table C1). Consumption in these countries will be spurred by more rapid growth in economic activity relative to the OECD and CPE countries, particularly among the newly industrialized countries of Asia; resultant increases in energy-intensive economic activity; and, in many countries that import oil, the inability to afford energy alternatives. To the extent that they occur, urbanization and electrification add considerably to energy and oil consumption per capita. A major uncertainty concerning growth in oil demand in the developing countries arises from the growing problem of Third World debt. Given its large resource base, oil consumption for OPEC as a whole will be limited only by the amount demanded.

World oil consumption has accelerated since the major oil price decline in 1986 and is expected to continue its relatively rapid growth during the early 1990's in response to stable prices. Growth in oil consumption is projected to then moderate in the late 1990's and beyond, in response to rising prices. This interaction between price and consumption has occurred frequently in the past, as might be expected of goods traded in the marketplace. For example, oil consumption rose rapidly in the 1960's when prices were flat. However, consumption in the OECD countries declined markedly after the first oil price shock of 1973/74. As prices settled down, consumption increased again, reaching a peak in 1979. The second oil-price shock in 1979/80 caused oil consumption in the OECD countries to drop once again, reaching a low in 1983. As in the past, oil consumption has grown subsequently in response to the price collapse in 1986 and a second decline in 1988.

In 1988, oil consumption in the Market Economies exceeded 50 million barrels per day for the first time since 1979. Possible negative influences of low world oil prices, particularly given the prospects for reduced non-OPEC supplies in the future, are that low prices can discourage necessary investments in energy-savings and fuel-substitution activities and in oil exploration and development.

Oil consumption in developing countries has been less sensitive to changes in world oil prices, increasing steadily through the two price shocks of the 1970's.

Consumers in the oil exporting developing countries, including OPEC, have been protected from much of the change in the price of oil sold on the world market. Many of the oil importing countries have not had the investment capital required to shift from oil when prices rose. It is likely that oil consumption in the developing countries will continue to grow, particularly in the near term when prices are expected to remain low.

Given the limited ability to substitute other fuels for oil in the transportation sector, oil consumption in this sector has been less sensitive to price changes than in the other major economic sectors, such as the industrial and electric utility sectors. Among the OECD countries, much of the recent growth in oil consumption has been in the transportation sector. Oil is expected to continue to dominant the transportation sector throughout the projection period. As a result, policies addressing automobile fuel efficiency could have an important impact on oil consumption and oil conservation in the future.

Policies that address environmental concerns could also influence prospects for oil consumption in the motor vehicle transportation sector. Restrictions resulting from environmental concerns would not necessarily reduce the total amount of oil consumed, though they probably would have some effect. These restrictions would influence the makeup of refinery yields, however, by encouraging production of lighter products, including lead-free gasoline.

Declining use of oil in the electric utility sector is expected to continue over the projection period, due both to environmental and security concerns. For example, nuclear power lacks the problems of air-pollution associated with the fossil fuels; and, among the fossil fuels, natural gas produces less sulfur dioxide and less carbon dioxide than do oil or coal. A switch from oil to natural gas and nuclear power would also serve to diversify the fuel mix used in manufacturing and electricity generation. Increasing the relative importance of these fuels, along with that of coal, would increase energy security through diversification of energy supplies.

Motor gasoline and jet fuel are the major fuels used in the transportation sector; and, given the lack of suitable substitutes, the consumption of these fuels is expected to grow, at least through the year 2000. As in the United States, automobile travel should continue to grow, though at reduced rates from past levels. Efficiency gains should help to moderate the overall growth in motor gasoline consumption, though incentives to improve fuel efficiency have been dampened recently by lower prices. Air travel is expected to grow along with overall economic activity but, again, at reduced rates from past levels.

Consumption of distillate fuel oil used in the industrial and electric utility sectors is also expected to grow over the next 20 years. Growth will come primarily from use in the industrial sector. Consumption of heating oil should grow only moderately between now and 2000, possibly leveling off thereafter as gas and electricity continue to penetrate this market. After a precipitous decline following the oil price shocks of the 1970's, consumption of residual fuel oil should grow moderately for a time. Lower prices have increased its competitive position relative to coal and natural gas recently, but higher prices could reduce its use once again.

Influence of Refinery Trends

World refining capacity is projected to grow in both crude distillation and downstream units in the next few years to keep up with growing demand. Refining capacity is rising again after a steady decline beginning in 1981. This new trend reflects a number of changes in the world oil market. First, world oil demand is not only growing again, but the composition of the demand is continuing to shift from a heavier product slate to a lighter product slate. Second, to meet the growing and changing demand, both the world refining capacity and refinery configuration have been enhanced. As a result of the changing demand and changing refinery configuration, refinery output, which is characterized by joint-product effects, should affect product trade patterns in the near future.

World oil demand started declining in 1979 when the Iranian revolution caused a steep rise in crude oil prices. Refining capacities, which reflect the ability of the refining industry to meet the demand for refined products, also underwent a transition following the decline in demand. Adjustments of refining capacities are slow, however, because of the delay between the planning of and the actual completion of new capacities and the shutdown of existing refining facilities.

Declining world oil demand reversed in 1984, and the collapse of world oil prices in 1986 stimulated oil demand further. This increase in demand finally caught up with world refining capacity and changed near-term prospects for the refining industry. A general rule is that for refineries to be profitable, the utilization rate must be around 85 percent. In 1987, world oil consumption exceeded 85 percent of crude capacity. This relationship indicates that world refining capacity has reached a stage that is more compatible with world demand for oil. In the near future, crude oil distillation capacity is expected to grow as oil demand grows.

Several noticeable changes have taken place in the refining industry since 1981. Most significantly, capacities of downstream conversion units such as catalytic-cracking and thermal-cracking units have been increasing, while crude oil distillation capacity has been steadily decreasing. Both catalytic cracking and thermal cracking units are aimed at converting the "bottom of the barrel" to lighter and more valuable products such as gasoline and distillates. The deviation between the trend of the crude distillation capacity and capacities of downstream units reflects a fundamental change in the composition of demand for refined products and the economics of petroleum refining. For example, Market Economies output levels for gasoline, jet fuel, and distillate declined in 1981 from the 1980 level, but started to increase in 1982, despite the continued decline in total output in 1982 and 1983. The output share of gasoline and distillate continued to increase through 1987.

The shift of product share from residual fuel to more valuable gasoline and distillate has dictated world trends in refinery configurations. Capacity of crude distillation units declined steadily from 1981 through 1986. Catalytic cracking capacity increased from 1981 through 1984, declined in 1985 and 1986, but increased again in 1987. Thermal cracking capacity showed a steady increase from 1981 through 1987. These changes in the configuration of refining capacities reflect a fundamental change in the operation of refineries to meet both product demand and changes in product specifications.

Recent developments in the United States and Europe will also have effects on refinery configurations in the near future. The lead phasedown program in the United States has increased the need to produce gasoline blending components capable of raising octane numbers. The United States regulation on Reid vapor pressure reduced the demand for butane as a gasoline blending component. Since butane is a good source of octane, a reduction in the use of butane will raise the burden on refiners to increase the production of other gasoline-blending components to raise the octane number. At the same time, the release of butane as a gasoline component will likely lower its market value and, consequently, affect refiners' profit margins. Industry adjustments to regulations on Reid vapor pressure are expected to include options such as use of higher octane catalysts in the fluid catalytic cracker, increased reforming severity, and the use of high octane blending stock such as methyl tertiary butyl ether.

In Europe, the conversion of military jet fuel from naphtha type to kerosene type will raise the demand for kerosene but decrease the demand for naphtha. The change will also reduce military demand for gasoline. The switch of naphtha from military use to commercial use would increase feedstocks for use as petrochemicals or for use in reformers to augment the supply of a higher octane blending component for gasoline. In a period of high demand for petrochemical products, this shift of jet fuel usage is welcome. However, the increase in worldwide petrochemical production capacity in recent years and the prospect that natural gas may compete with naphtha in the petrochemical industry could diminish the benefits of this change to the European refineries. All these changes will influence the economics of refinery operations and the development of refinery configurations.

In addition to the changes in world refinery configurations, there will likely be changes in the distribution of world refining capacity as well. After the 1979 oil price shock, world oil demand declined. The reduction in oil consumption, however, came mainly in the OECD countries. Demand for oil actually rose in the developing countries. It is expected that the increase in demand for oil in developing countries will play an important role in determining the distribution of additional world refining capacity.

Refinery output from these countries should affect future product trade significantly because of the joint product effect of the refinery process. For example, the 1984 coal strike in the United Kingdom increased demand for heating oil, and resulted in increased production of fuel oil, gasoline, and other light products. Excess supplies of these refined by-products were then sold in international markets and affected both product prices and trade flows.

World Energy Consumption

Consumption of total primary energy is projected to grow steadily between now and 2010 throughout the world spurred primarily by continued economic growth. Oil will be the most important single source of energy through the year 2010, but its relative importance is expected to decline steadily. All other fossil fuels are projected to increase in relative importance, as is nuclear power. Projections of total primary energy by energy source are presented in Table C2. As with economic growth, energy consumption is projected to grow most rapidly in the developing countries, possibly twice as fast as in the OECD countries or in the CPEs (Table C3).

Energy Efficiency

Energy consumption is expected to grow less than economic activity, as the energy intensity of economic activity (defined as the ratio of energy consumption to gross domestic product) continues to decline (Figure ES3). A measure of overall efficiency, energy intensity in the OECD countries is expected to decline but at a slower rate than the rate experienced after the oil price shocks of the 1970's. Relatively low energy prices will provide less incentive for investments in energy conservation and efficiency. Nevertheless, technological progress should continue to be a significant contributor to energy efficiency gains in the future, as it has been in the past. Technology can contribute to efficiency gains by improving the fuel utilization in buildings, appliances, and vehicles and also by reducing the level of fuel required to produce products in the manufacturing process. An important example of this is in the manufacture of steel where production improvements and steel substitutes have reduced the consumption of metallurgical coal.

Energy to gross domestic product ratios in the OECD countries are expected to decline in the future because of increasing energy efficiency and also because of changing economic structure. The increase in the services and high-technology industries relative to heavy manufacturing and resource development is expected to continue and to contribute to a mix of economic activity that is generally less energy intensive. At the same time, traditional heavy manufacturing has increased outside of the OECD countries, particularly in the newly industrialized countries. This shift in activity has and will continue to change the energy intensity of economic activity in the respective regions.

The energy intensity of economic activity in the developing countries should also improve modestly over time. Improvements in these countries are difficult, for many countries are dependent on energy-intensive natural resource development for desired economic growth. Growth will also encourage increases in motor transportation and in electrification, both relatively energy intensive activities.

The oil intensity of economic activity in the developing countries will likely remain higher than in the industrial world. The industrial countries have and should continue to reduce the amount of electricity produced by oil, substituting nuclear, hydroelectricity, and other fossil fuels for oil. Fuel switching and fuel substitution efforts require large start-up capital expenditures, however, and many developing countries would have to borrow in order to create the needed infrastructure. Given the large foreign debt already carried by many countries, particularly in Latin America, the required capital could become increasingly more difficult to obtain.

Oil consumption patterns in the oil exporting developing countries should also contribute to the higher overall oil intensity of economic activity in these countries. The consumption patterns in OPEC, for example, has been quite different than the patterns in the OECD countries or in other developing countries (Figure ES3). The energy intensity of economic activity in OPEC, as measured by the energy to gross domestic product ratio actually rose in the late 1970's and early 1980's while the ratio for all other groups of countries was either flat or declining. As might be expected, oil consumption continued to grow in oil-rich OPEC. Further, oil accounts for a large portion of total energy consumed by OPEC. Finally, the price of oil dropped precipitously after 1981, taking oil revenue and gross domestic product down as well. Thus, the increase in the OPEC energy to gross domestic product ratio was due not only to an increase in total energy consumption, but also to the decrease in the gross domestic product.

Changing Fuel Shares

Oil will continue to be the world's single most important source of energy over the next 20 years, but growth in oil consumption is expected to proceed at a much lower rate than that of other energy sources. The price hikes of the 1970's and prospects for additional price increases in the late 1990's and beyond should encourage the substitution of other energy sources for oil. At the same time, low prices have reduced incentives to shift from oil

in recent years, as benefits from fuel substitution and oil conservation become less certain. Low oil prices in the early 1990's will likely continue to reduce the rate at which alternative fuels might otherwise be substituted for oil and could discourage the investments needed to ensure future substitution. Nevertheless, the next 20 years should see oil's share of the energy market continue to decline.

Natural gas is expected to be the fastest growing fossil fuel through the year 2010. Natural gas supplies are abundant relative to oil supplies and relative to its lower absolute level of consumption. In 2010, for example, natural gas would still supply only about one-half as much of the energy needs in the Market Economies compared with oil's contribution. The increased use of natural gas will bolster energy security in many countries by reducing dependence on oil imports, and it will reduce the environmental problems associated with the use of other fossil fuels, particularly coal.

Growth in coal consumption will come primarily to help meet increasing demands for electricity. Hydroelectric and nuclear power will also contribute to the growing production of electricity. Changes that have occurred in the structure of the electricity supply industry since the oil crisis of 1973 have been responsible for much of the decline in oil consumption that has occurred to date. For example, between 1973 and 1987 the amount of electricity produced from oil among the member countries of the International Energy Agency (IEA) dropped by one-half, even while total electric generation was rising by 46 percent. France, Finland, and Ireland are members of the OECD but not the IEA. Coal and nuclear power have been the major substitutes for oil over this period.

Increased consumption of electricity among the OECD countries is projected to account for much of the increased consumption of energy in the residential/commercial and industrial sectors. The relative importance of oil to produce increased amounts of electric power in the OECD countries declines, while that of the other fossil fuels rises. The absolute use of oil to produce electricity could rise then fall once again, depending on the price of world oil, given the availability of dual-fired or oil-fired generating capacity. In contrast, oil will be the dominant fuel in the transportation sector among the OECD countries and elsewhere, given the lack of suitable substitutes.

The shift from oil to other fuels to produce electricity will be difficult for many developing countries, however, because of the large capital requirements needed to develop these alternatives. Environmental problems associated with the use of coal, nuclear, and hydroelectric power could inhibit the growth of these alternatives in all parts of the world. The extent to which these energy sources are developed will depend to a significant degree on the technological advances made and the methods used to reduce associated environmental costs.

Coal consumption raises environmental concerns about sulphur dioxide and carbon dioxide emissions. Sulphur dioxide contributes to acid rain. Carbon dioxide is considered a "greenhouse" gas. These emissions are far less from natural gas than from coal and are absent from nuclear power, though nuclear energy raises other environmental concerns. As a result, coal should face strong competition from natural gas and nuclear, in the generation of electricity.

Synthetic Oil and Other Liquids

Synthetic oil and other liquids include liquids from coal liquefaction, ethanol, and methanol. These products satisfy, mainly, the demand for gasoline. Forecasts of these liquids consider technologies available today and the cost of producing those technologies relative to the price of crude oil. In general, coal liquefaction plants are the most expensive to build and require 4 to 5 years to complete. Production costs of ethanol and methanol are higher than that of coal liquefaction. It is estimated that the price of crude oil must be above $40 per barrel for ethanol and methanol to be competitive.

Given current costs and technologies, it is estimated that the cost of crude oil would have to exceed $35 per barrel in 1989 dollars for at least 4 consecutive years for commercial production, in the range of 100,000 barrels per day, of synthetic liquids to occur. This delayed response of production to price increases reflects the planning and construction time required to complete a coal liquefaction plant. Once established, production capacity would not be lost, even if the price of oil drops below $35 per barrel. At $40 per barrel of crude oil, synthetics could be highly competitive and production could accelerate rapidly.

In the Market Economies, the most likely producers of synthetic liquids are the United States, South Africa, West Germany, the United Kingdom, and Japan. Currently, South Africa is capable of producing about 65,000 barrels per day of liquids from coal. Production costs should decline as technologies improve. Currently, Japan, West Germany, the United Kingdom, and the United States have coal liquefaction research and development programs.

The United States will find it difficult to compete with foreign methanol producers as long as natural gas is a primary ingredient. However, prospects for methanol

production in the United States would improve considerably with a price for crude oil in excess of $35 per barrel, a point at which methanol from coal could become feasible.

Regional Energy Issues

Starting from a relatively low base, much of the growth in total energy demand will come from the developing countries as the result of greater population growth and increasing urbanization and industrialization. A large part of the growth in economic activity is concentrated among the newly industrializing countries, particularly along the Pacific Rim, where manufacturing activities have grown substantially. Countries with high population growth will experience the most rapid rate of urbanization and the requisite fuel requirements.

Urbanization tends to increase energy consumption as the labor force shifts from agriculture to industry and services and from smaller to larger scale manufacturing. Larger scale production requires larger markets and increased transportation of materials, products, food, and other essentials--both in quantity and distance. In agriculture, reduced labor intensity means increased energy intensity through increased use of machinery. There is still much potential for urbanization worldwide. It is estimated that in the populous countries of China and India, less than one-fourth of the population is now urbanized.

The major industrial regions have become increasingly energy efficient during the 1970's and 1980's and are projected to continue to improve efficiency through the year 2010, though at a reduced rate (Figure ES3). The developing countries experienced rising energy consumption per real gross domestic product over the past 2 decades, but they too are projected to demonstrate increasing efficiency over the next 2 decades. The growing scarcity projected for oil supplies outside of the Persian Gulf region and tightening supplies of other energy sources will require improved energy efficiency among the developing countries even as they try to encourage economic growth. Unless new sources of indigenous energy supplies are found in the energy importing developing countries, inefficient use of energy could result in rapidly rising prices, particularly as world energy markets tighten. If prices begin to escalate, the wealthier industrial countries would be in a stronger position to purchase available resources. Thus, to the extent they must import energy, developing countries must focus on energy efficiency, as they build their industries and their electricity and transportation networks. Energy consumption could well grow twice as fast in the developing countries as in the OECD countries or in the Centrally Planned Economies taken as a group.

As today, the large economies of the United States and the Soviet Union are projected to remain the largest consumers of energy through the year 2010. Among the Market Economies and in absolute terms, the OECD countries together are expected to account for a large share of total energy consumed in the future as they do today. For example, much of the growth in total energy consumed in 1988 occurred in the OECD countries, again in absolute terms, and much of the OECD growth occurred in the United States.

At the same time, energy resources differ widely among the OECD countries. Japan, for example, must import much of the energy it requires because of the virtual absence of indigenous energy resources. The lack of resources is expected to encourage Japan to expand nuclear production substantially over the projection period. Imports of natural gas to Japan could grow as fast or faster than consumption of nuclear power. Japan could reduce its energy vulnerability considerably by diversifying its sources of energy.

Natural gas should grow in importance within Europe as well. Preference for natural gas results from its clean-burning characteristics, particularly relative to coal; and, as in Japan, use of natural gas would serve to diversify energy requirements. But, increased use would also require increased levels of imports. Major natural gas reserves exist in the Middle East and in the Soviet Union. As a result, trade among these regions and the OECD countries of this important energy source should grow in size and importance.

Prospects for nuclear power vary considerably among the OECD countries. Like Japan, France is emphasizing nuclear power to counter the lack of indigenous energy resources. OECD countries, such as the United States, France, Japan, and West Germany dominate the nuclear industry, though nuclear power production in the Soviet Union is currently comparable to that in France. Several European countries are scaling back on plans for nuclear development due to concerns about plant safety and waste disposal. The accident at Chernobyl in 1986 increased these concerns in Europe and reduced production in the Soviet Union in 1986. However, Soviet production resumed its rapid growth in 1987 and 1988.

There is and will continue to be considerable diversity among the OECD countries in terms of energy use. Turkey, for example, uses the least amount of energy per capita. For example, in 1988, the ratio of total primary energy requirements (TPER) to gross domestic product (GDP) was 2.8 times greater in Turkey than it

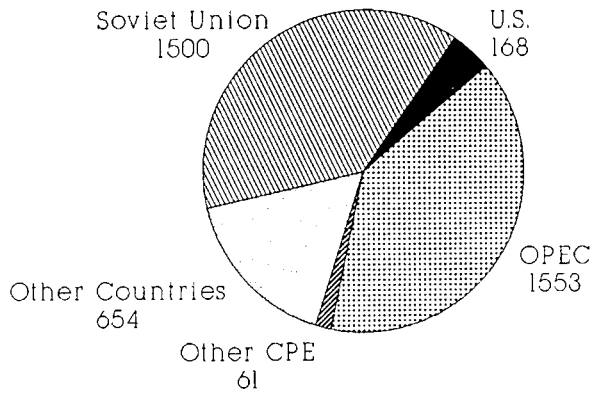
was in Japan, the country with the lowest TPER/GDP ratio. Yet, the ratio of TPER/per capita was 3.5 times greater in Japan than in Turkey. The United States TPER/per capita ratio was 8.5 times greater than in Turkey and 2.4 times greater than in Japan. Low energy use per capita but high energy use per unit of output is a characteristic Turkey shares with many less developed countries. High TPER/per capita ratios indicate the potential for greater energy saving in the future through conservation. This situation holds for the United States and, to a lesser degree, for Japan but not for Turkey. On the other hand, high TPER/GDP ratios indicate the potential for energy savings through improved efficiency. This situation applies to Turkey to a greater degree than to Japan or the United States. Of course, aside from the efficiency question, industry mix is also an important determinant of the TPER/GDP ratio. The greater proportion of activities with low energy intensity, such as the services and high-technology manufacturing, compared to activities with high energy intensity, such as heavy manufacturing and natural resource development, the lower the TPER/GDP ratio.

Prospects for Natural Gas

Natural gas is projected to be the fastest growing fossil fuel in the world through the year 2010. In the Market Economies, natural gas is also expected to grow faster than nuclear power. Natural gas exceeded oil as the primary source of energy in the Soviet Union in 1986 and will remain its major source over the projection period. With relatively abundant reserves worldwide (Figure 14), countries are planning to use natural gas to reduce dependence on oil and to reduce the environmental problems associated with other fossil fuels, such as coal. Other factors that will influence natural gas consumption include its price relative to prices for other energy sources, the availability of capital to develop new sources and construct required distribution systems, the development of more competitive markets, and overall growth in economic activity. Projections of natural gas consumption are presented in Table C4 and Figure 15.

Natural gas generally competes with petroleum products, particularly in the residential, commercial, and industrial sectors. However, in the electric utility sector, natural gas may compete increasingly with coal rather than oil. Several factors will encourage the use of natural gas for electric power production in Europe, and elsewhere, including raised expectations concerning supplies, increased concern over the environmental problems associated with power produced from coal and nuclear plants, relaxation of restrictions on the use of natural gas for electricity production, expected growth in the use of gas-fired combined-cycle units to meet future requirements, and prices that remain competitive with other fuels.

Figure 14. World Natural Gas Reserves, January 1, 1989 (Trillion Cubic Feet)



Source: See Appendix D.

Increased use of natural gas by electric utilities is also anticipated in the United States, in part due to the 1987 amendment to earlier legislation that placed restrictions on the construction of new baseload, gas-fired generating units. Though consumption of natural gas is expected to grow significantly in the electric utility sector, growth in the residential and commercial sectors should be limited by the penetration of electricity and efficiency gains in the use of natural gas. Consumption in the industrial sector is expected to grow faster in the early 1990's than afterwards. This pattern of growth in gas consumption should hold for the OECD countries as a whole.

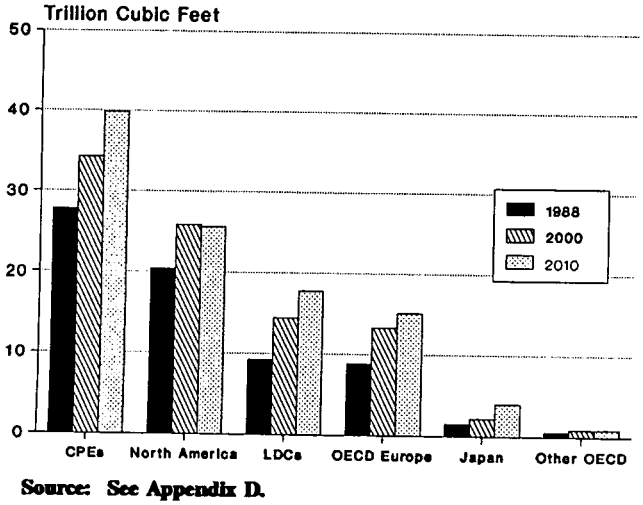
Imports of natural gas to the United States are expected to become increasingly important in the future. Imports represented about 7 percent of total United States consumption in 1988. Canada is and should continue to be the major source of imported natural gas. The Free Trade Agreement negotiated in 1987 and ratified by both countries in 1989 is intended to encourage free trade between the United States and Canada, including a more integrated natural gas market. If future prices for United States natural gas rise along with the projected rise in oil prices, incentives to increase Canadian imports would likely rise as well.

Natural gas imports to OECD countries from non-OECD areas differ considerably by region. According to the IEA, the OECD as a whole imported 12 percent of all gas consumed in 1987. The amount from non-OECD sources was 25 percent in OECD Europe and 67 percent in the Pacific region (Japan, Australia, New Zealand). North America, in contrast, was self-sufficient.

With these imports, natural gas supplies are sufficient to meet demands among the OECD countries. Significant additions to future supplies within the OECD are expected from the North West Shelf project in Australia and the Troll/Sleipner complex in Norway. Additional supplies are also expected from the Soviet Union, given extensive investments in the production and distribution of natural gas.

As with oil, consumption of natural gas is expected to grow most rapidly in the developing countries. Natural gas reserves are abundant in many developing countries, particularly in the Middle East. Expansion of industrial production through increased use of domestic resources is, according to many gas-producing countries, one method of indirectly exporting a product which, otherwise, is difficult and expensive to transport. As elsewhere, natural gas, again primarily from indigenous sources, is also expected to be used increasingly for the production of electricity. The extent to which natural gas resources are developed within these countries will often be highly dependent on the availability of foreign investments.

Figure 15. World Natural Gas Consumption, 1988, 2000, and 2010



Source: See Appendix D.

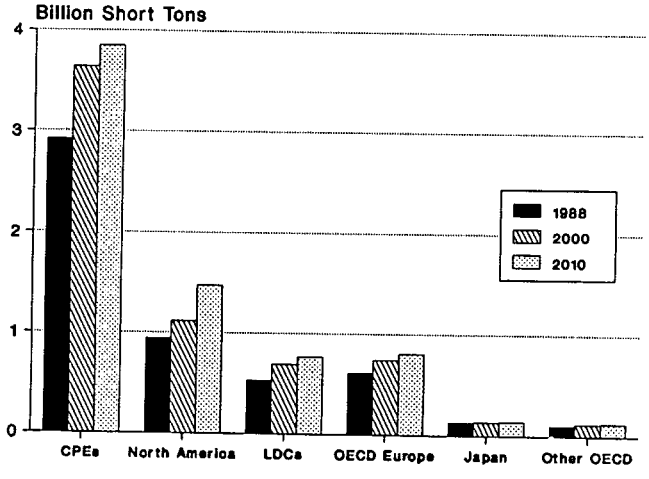
Prospects for Coal

Consumption of coal is expected to grow steadily throughout the projection period and to gain somewhat in relative importance (Table C5 and Figure 16). Coal is and will continue to be the most important energy source among the Centrally Planned Economies, other than the Soviet Union. Major contributors to the growth in coal demand are increased use for the production of electricity and continued desire for supply diversification. Increased demand and limited supplies in Western Europe and Asia, excluding China, will contribute to growth in international coal trade. Major exporters include Australia, the United States, South Africa, and Poland. New sources of supply include those in China, Colombia, and Venezuela.

Coal prices are expected to remain relatively low over the long term. Helping to keep prices low are large reserves worldwide and excess production capacity (Figure 17). Low prices have caused financial difficulty among mining operators and developers who made investment decisions in the early 1980's when energy prices were high. As a result, there has been and will continue to be a major restructuring of the coal industry to reduce high-cost production operations, particularly in Europe. This is true even in West Germany, which historically has sought to protect indigenous coal operations from foreign competitors.

The coal industry in Europe will be further affected by its goal of establishing a free-trade community by 1993. An additional uncertainty concerning coal supplies for Western and Eastern Europe is the ability of Poland and the Soviet Union to maintain desired production levels, given competing demands for domestic investments.

Figure 16. World Coal Consumption, 1988, 2000, and 2010

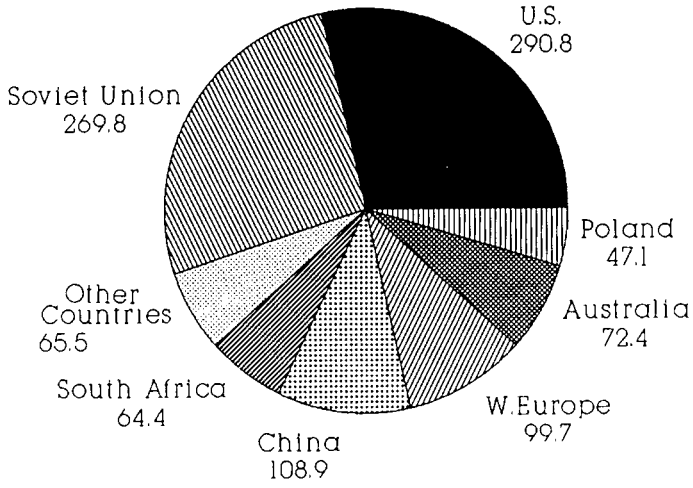


Source: See Appendix D.

Coal exports by the United States expanded from 79.6 million short tons in 1987 to 95 million short tons in 1988. United States exports should remain at the 1988 level through the mid-1990's and then expand, primarily as the result of increased demand from the United Kingdom and West Germany. Higher United States exports in 1988 resulted from unexpected reductions in supplies from Australia, China, Colombia, and Venezuela and unexpected increases in steel production and electricity demand. However, coal from these regions

will compete with the United States exports in the future. Exports to the United Kingdom are expected to grow as the United Kingdom proceeds to privatize its electricity industry, which will eventually be free to purchase coal on the world market.

Figure 17. World Coal Reserves (Billion Short Tons)



Source: See Appendix D.

Growth in coal consumption is expected to come primarily from demand for steam coal to produce electricity rather than for metallurgical coal to produce steel. Demand for steel is expected to grow only moderately over the projection period. Demand for metallurgical coal will also be tempered by improved technology in steel production and increased use of steel substitutes. Environmental concerns about sulphur dioxide (acid rain) and carbon dioxide (greenhouse gas) could constrain the growth of steam coal consumption, though improvements in cleaning coal emissions and innovations in clean coal-burning techniques are anticipated.

Prospects for Nuclear and Other Energy Sources

As the new decade begins, it is difficult to find cause for optimism regarding the future of nuclear power, at least in the short to medium term. The problems with nuclear power center around three main issues: its low level of public acceptance, particularly since the Chernobyl disaster; its economics, especially in the context of low fossil fuel prices; and its own unique environmental problems, the most important of which being the disposal of radioactive waste. This is not to say that there are no factors working in favor of nuclear power. For instance, concerns have increased dramatically over the last year regarding the environmental problems associated with the burning of fossil fuels. This factor alone may prove strong enough to provide a significant boost to nuclear power, particularly in the long run. In the short term, however, it is probable that nuclear power will grow slowly, due to the negative factors mentioned above.

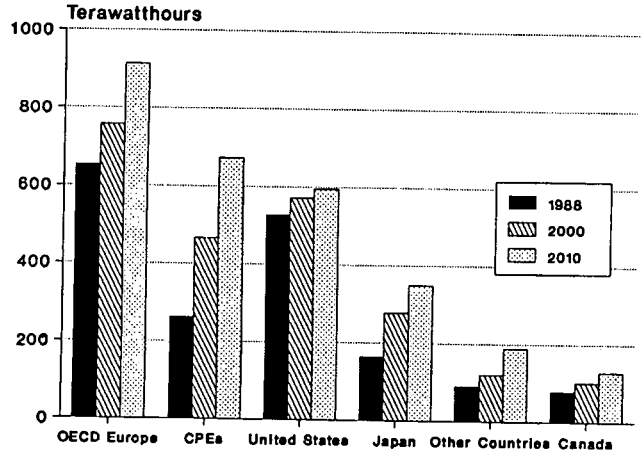
Some of the same negative factors facing the nuclear power industry at this time also confront the "renewable" energy sources sector. Hydroelectric power, for instance, has huge potential in many parts of the world, but its development is hampered by the same three issues hindering nuclear power: public acceptance, economics, and its own particular environmental problems. The proposed "Three Gorges" plant in China is a good example of these problems. As currently envisaged, the 607-foot high dam on the Yangtze River would be the world's largest hydroelectric project, producing up to 18 gigawatts of electricity when completed sometime after the year 2000. Whether the dam will ever be built, however, has been called into doubt for three main reasons: cost (at least $10 billion at today's prices), public opposition (the dam would displace up to a million people), and environmental problems (it would inundate one of the country's most scenic areas). On the other hand, energy is of crucial importance to China, as it is to other developing countries. Despite all the problems associated with nuclear and renewable power sources, it is likely that these countries will be forced to consider their development as a means of reducing dependence and of maintaining desired levels of economic growth.

Perhaps the most hotly debated topic in the entire energy arena in 1989 involved a phenomenon known as "cold fusion." Initial claims indicated that this "relatively simple" technique could, in the words of the *Financial Times,* "provide virtually unlimited, clean and inexpensive energy." Enthusiasm soon turned to skepticism, however, as scientists failed to verify the original findings. On the other hand, several laboratories have continued to report "inexplicable" amounts of energy from electrolysis devices containing palladium rods immersed in heavy water. At the present time, it has not been determined whether this energy is the result of "cold fusion," some other phenomenon, or measurement error. It is thus impossible to speculate on the potential for any practical results in energy production systems.

Nuclear power consumption is expected to grow at a slower rate after 2000 than in the preceding years, reflecting the drop in the growth rate of additions to nuclear generating capacity. Nuclear power, which was estimated to account for 5.7 percent of total world energy consumption in 1988, is projected to account for about 7.0 percent in 2010 (Table C6 and Figure 16).

France is currently exporting approximately 40 net terawatthours of nuclear-generated electricity to other European nations and may be exporting over 60 net terawatthours by 2010. Estimates of nuclear exports from France have been excluded from French nuclear consumption in Table C6 and Figure 19 and have been included in the consumption figures for traditional French customers, including the United Kingdom, West Germany, Italy, the Netherlands, and three countries (Belgium, Spain, and Switzerland) in the "Other Europe" region. Thus, the projections of nuclear consumption for these countries (in particular, Italy) do not necessarily reflect the trends in their domestic nuclear power programs.

Figure 18. World Nuclear Energy Consumption, 1988, 2000, and 2010



Source: See Appendix D.

Overall prospects for nuclear power are relatively pessimistic, but the outlook varies from country to country.

- A decision on whether to build Finland's fifth nuclear plant has not yet been made, and most likely will not be until a new government is elected in 1991. Recent public opinion polls indicate that nuclear power has regained about the same level of support as before the Chernobyl accident.

- The prospects for nuclear power in Italy remain poor. Current government policy calls for no more nuclear power to be generated in the country. Existing plants are to be mothballed (Caorso), decommissioned (Trino, Latino, Garigliano), or converted to gas/oil/coal-fired stations (Montalto di Castro).

- The Dutch government postponed a decision on building more nuclear capacity at least until 1990, when national elections are expected to be held. Plans to add some 3,000 megawatts of additional nuclear capacity have been shelved since Chernobyl.

- Recent public opinion surveys in Spain show nuclear power to be a relatively unpopular energy option, with over 70 percent of the Spanish population considering nuclear to be more dangerous than other methods of power generation. This lack of public support makes it unlikely that the 5-year old moratorium on nuclear power plant construction will be lifted anytime soon. Another serious setback to Spain's nuclear industry occurred on October 19, when the Vandellos I plant suffered a fire that was the worst accident ever at a Spanish nuclear plant.

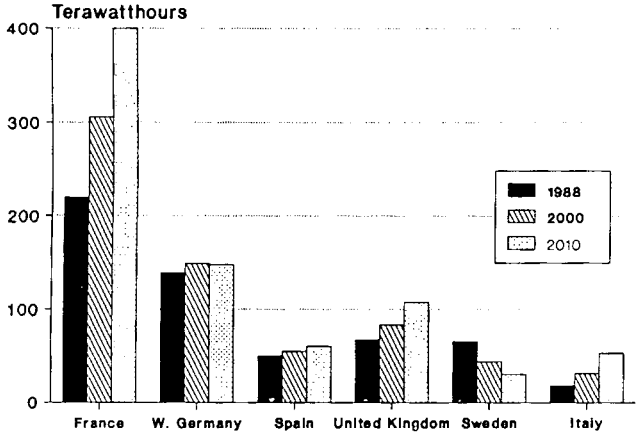
- Sweden continues its plans to completely phase out nuclear power by 2010, even though estimates of the economic losses that this would entail reach as high as $15 billion. Nuclear power currently satisfies nearly 50 percent of total Swedish electricity demand. With this demand growing at about 1 percent per year, it will be difficult for Sweden to achieve its three main energy goals of phasing out nuclear power, stabilizing carbon dioxide emissions, and preserving its last four major unused rivers from hydropower development.

- The French remain fundamentally committed to nuclear power, but are faced with a situation of growing overcapacity and debt on past construction. Construction of new nuclear plants has slowed dramatically from the rate achieved during the 1970's and 1980's. On the other hand, rising demand for French electricity exports in neighboring countries, especially in the context of a unified European energy market after 1992, offers future opportunities for expansion of French nuclear generating capacity.

- With over 54 gigawatts-electric of nuclear generating capacity either in place or in the construction pipeline, Japan remains one of the countries most firmly committed to nuclear power. Even in Japan, however, there are problems relating to public acceptance of nuclear development. Underlying social trends have created an increased level of concern among the Japanese public regarding environmental issues in general, and nuclear power in particular. This issue of public acceptance has already complicated Japan's ambitious nuclear program, and will most likely continue to do so in the coming years.

- South Korea, like Japan, has historically been attracted to the nuclear power option as a way of compensating for its relative lack of indigenous energy resources and of reducing its dependence on imported oil. Nuclear power plants currently supply approximately one-half of the country's electric generation capacity, and the Korean Energy Resources Ministry is planning on having 14 nuclear plants in operation by the year 2000. With electricity consumption projected to maintain its current high rate of growth well into the next century, at least one study has concluded that South Korea will need to build up to 50 nuclear power plants by the year 2030 to meet the demand.

Figure 19. Nuclear Energy Consumption in OECD Europe, 1988, 2000, and 2010



Source: See Appendix D.

The total world installed hydroelectric generating capacity as of 1988 was 593 gigawatts-electric. The share of world energy consumption, contributed by hydroelectric power, estimated at around 7 percent in that year, is expected to reach about 8 percent by 2010. Among the countries with significant amounts of hydroelectric power capacity in gigawatts-electric are: the United States (89.7); the Soviet Union (62.7); Canada (57.7); Brazil (40.1); Japan (36.4); China (28.0); Norway (25.4); and France (24.3). The world's largest hydroelectric plant is Itaipu, located on the border between Brazil and Paraguay, with an installed capacity of 10.5 gigawatts-electric. When the plant is fully completed in 1991, its total installed capacity will be 12.6 gigawatts-electric.

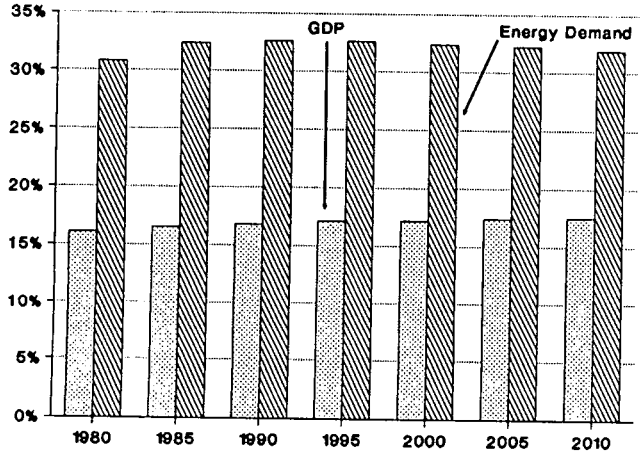
As of January 1, 1988, there were 228 geothermal power plants on-line worldwide, with a total capacity of over 5 gigawatts-electric: 1.5 in the United States, 0.9 in the Philippines, 0.6 in Mexico, 0.56 in Italy, 0.2 in Japan, and 0.1 in New Zealand. The total world consumption of geothermal electricity in 1987 was about 33 terawatthours. The consumption of geothermal energy by the developing countries (primarily, the Philippines, Mexico, and Indonesia) in that year was about 11 terawatthours, based on a total capacity of about 1.5 gigawatts-electric. In addition, there are currently 114 geothermal plants, with a total capacity of 1,754 megawatts, either under construction or in advanced planning stages. Projections of the consumption of "other" energy sources, including hydroelectric and geothermal power, are presented in Table C7.

Centrally Planned Economies

Net energy trade prospects between the Market Economies and the Centrally Planned Economies (CPEs) depend primarily on the outlook for CPE energy consumption and production. This outlook is complicated by recent political events: Mikhail Gorbachev's perestroika (restructuring) process, the democratization of Eastern Europe, and the Tiananmen Square massacre in China. The primary assumptions underlying the outlook presented here are:

- energy conservation will accelerate out of necessity;
- economic growth will be constrained by available energy resources;
- foreign currency earnings will remain a major consideration of energy trade policy of the Soviet Union and China.

Figure 20. CPE GDP and Energy Demand as a Percent of World GDP and Energy Demand



Source: See Appendix D.

The economic outlook for the CPEs varies considerably by country. Overall, the CPEs represent about 17 percent of total world gross domestic product and with economic growth rates expected to be between 2 and 3 percent for the next 2 decades, the CPE share of world gross domestic product (GDP) will remain about the same (Figure 20). The CPE share of world energy consumption is expected to decline somewhat, from roughly 33 percent in 1988 to 32 percent in 2010 (Figure 20). This decline reflects a larger energy conservation effort than that in the Market Economies over the forecast period.

Energy Reserves and Production

In 1988, CPEs had 84 billion barrels of proved crude oil reserves (approximately 8.5 percent of total world reserves), 1,560 trillion cubic feet of natural gas (approximately 40 percent), and 480 billion short tons of recoverable coal reserves (approximately 47 percent). Recent finds of natural gas in the Barents Sea and Kara Sea by the Soviet Union may add approximately 350 trillion cubic feet to CPE reserves. Although the CPEs have considerable reserves, extraction of these resources face long-term difficulties; namely, substantial reserves exist in inaccessible regions, much coal reserves are of low quality, natural gas infrastructure requires development, and oil fields have reached maturity. In addition, since the Chernobyl nuclear accident and the new glasnost (openness), the building of new nuclear units has been slowed.

Despite these difficulties, the potential remains for the region to be self sufficient and a net exporter of energy to the rest of world. More than offsetting the expected decline in CPE oil production is its natural gas production potential. Given competitive prices and assuming new access to West European markets, the natural gas market should expand. There are regional differences expected. Foremost, the Soviet Union will perhaps be able to exploit its resources at a faster rate than in the past, given the current climate under perestroika and new possibilities for joint ventures with the West. China will continue to export petroleum near current levels, albeit short of its plans of a few years ago. Except for East Germany and Poland, the countries of Eastern Europe face major problems with respect to energy supplies. Even though they will remain dependent for most of their energy on the Soviet Union, they will have to compete for these supplies with one another and with Western Europe, facing higher prices over time particularly for oil and to some extent for natural gas. These economies will be severely constrained by their capability to secure energy supplies. Further, the Soviet Union has suggested that petroleum supplies will have to be paid for in hard currency. Given rising world oil prices and the hard currency requirements of its dependent Eastern European countries, the Soviet Union will probably be able to maintain its current levels of foreign currency earnings for some time.

Coal Production

The largest coal producer in the world is China, followed closely by the United States and the Soviet Union. However, almost all of China's production is consumed domestically as is 95 percent of the Soviet production. The quality of the coal is quite different. Almost 90 percent of the United States coal is of high quality bituminous. Only 60 percent of the Soviet coal is bituminous. China's coal is nearly 100 percent bituminous. Like China, the dominant energy source of Eastern Europe is coal. Overall, the Soviet Union and the Eastern European countries produce about equal amounts of bituminous and lignite coal. In terms of recoverable coal reserves, the largest deposits exist in the United States, followed closely by the Soviet Union. China's reserves are about one-third the size of the United States. In 1988, Poland ranked sixth in the world.

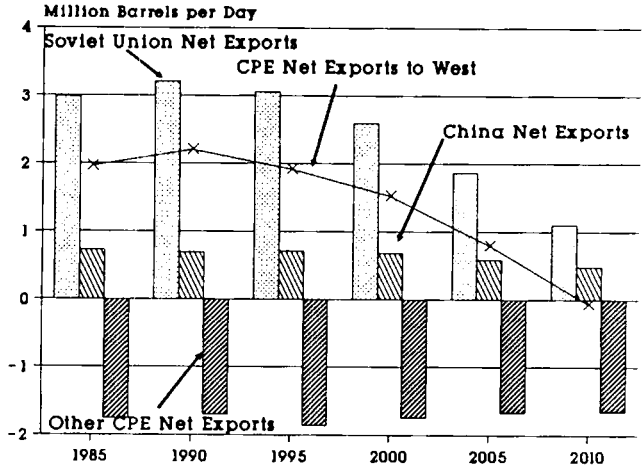
Although numerous short-term production problems exist (particularly labor strife), the outlook for coal production in China and Eastern Europe is for growth to satisfy increasing energy needs, particularly in light of declining petroleum resources and increasing costs. This is a real problem for the environmental concerns of the world.

Oil Production and Exports

It is generally expected that CPE oil production and, therefore, oil exports will decrease throughout the forecast period (Figure 21). The rate of decline depends on various factors, but primarily on the amount of capital that the Soviet Union will expend on improving machinery and equipment and for exploration of new fields. The amount of capital and drilling success will also be largely dependent on joint ventures with Western firms.

In 1988, the Soviet Union crude oil reserves were around 60 billion barrels with crude oil production of 11.7 million barrels per day, implying a reserve/production ratio of less than 14 years. Crude oil production is expected to fall between 1 to 4 percent per year, depending on the level of investments made in the petroleum area. The current emphasis on restructuring the Soviet economy more toward consumer goods suggests only modest investment in heavy industries, whereas almost 70 percent of past domestic investment has been in the heavy industry area. This past concentration of investment in petroleum kept domestic petroleum increasing to a peak level in 1987. Even with high investments, the Soviets will not be able to sustain production at current levels, given the maturity of their fields. Only China has significant production outside the Soviet Union.

Figure 21. CPE Regional Net Exports of Petroleum

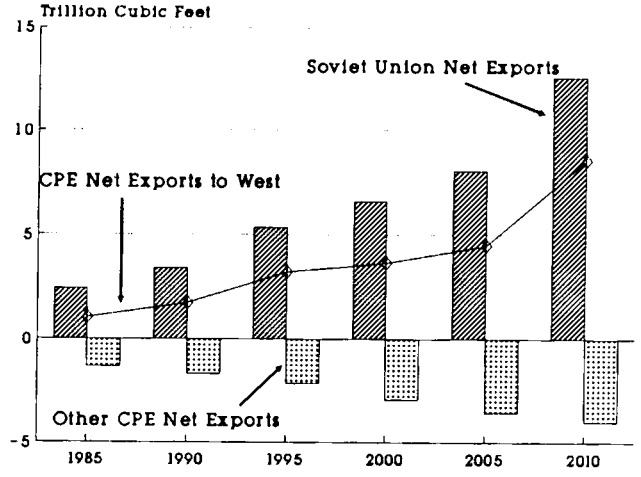


Source: See Appendix D.

Natural Gas Production and Exports

Given high reserves of gas and recent discoveries in the Barents and Kara Seas (potentially the largest fields in the world), the Soviet potential for natural gas production is enormous. However, geography and lack of investment capital will delay its replacement of oil as the major source of energy for domestic consumption and for export. Current exports to Western Europe of about 1.5 trillion cubic feet could double by 1995 and grow six fold by 2010, representing over 50 percent of the Western European gas market, up from 17 percent

Figure 22. CPE Regional Net Exports of Natural Gas



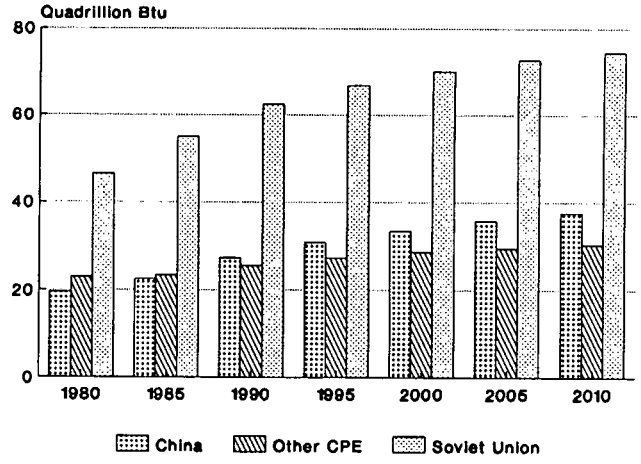
Source: See Appendix D.

in 1988 (Figure 22). Gas production is declining in the Eastern European countries and increasing somewhat in China.

Energy Consumption

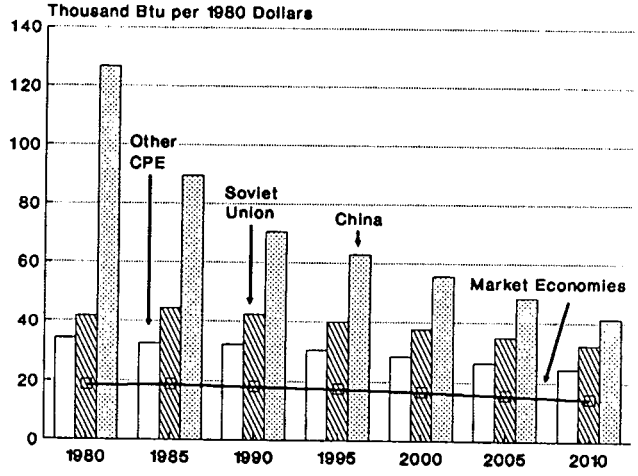
CPE energy demand represents 33 percent of total world demand, but only 17 percent of total world gross domestic product. This relationship implies the chance for considerable energy conservation in the future, with energy growing only one-third to one-half as fast as the gross domestic product (Figures 20, 23, 24). Most of conservation will be from reduced oil consumption, which may decline from 25 percent to 16 percent by 2010. More than making up for this decline will be the growth of gas, coal, and nuclear consumption (Figure 25). Chinese economic activity, however, will be severely constrained by decreasing indigenous energy resources, even after significant progress is made to conserve energy. China's energy/gross domestic product level is 3 to 4 times larger than that in the Market Economies.

Figure 23. CPE Regional Energy Consumption



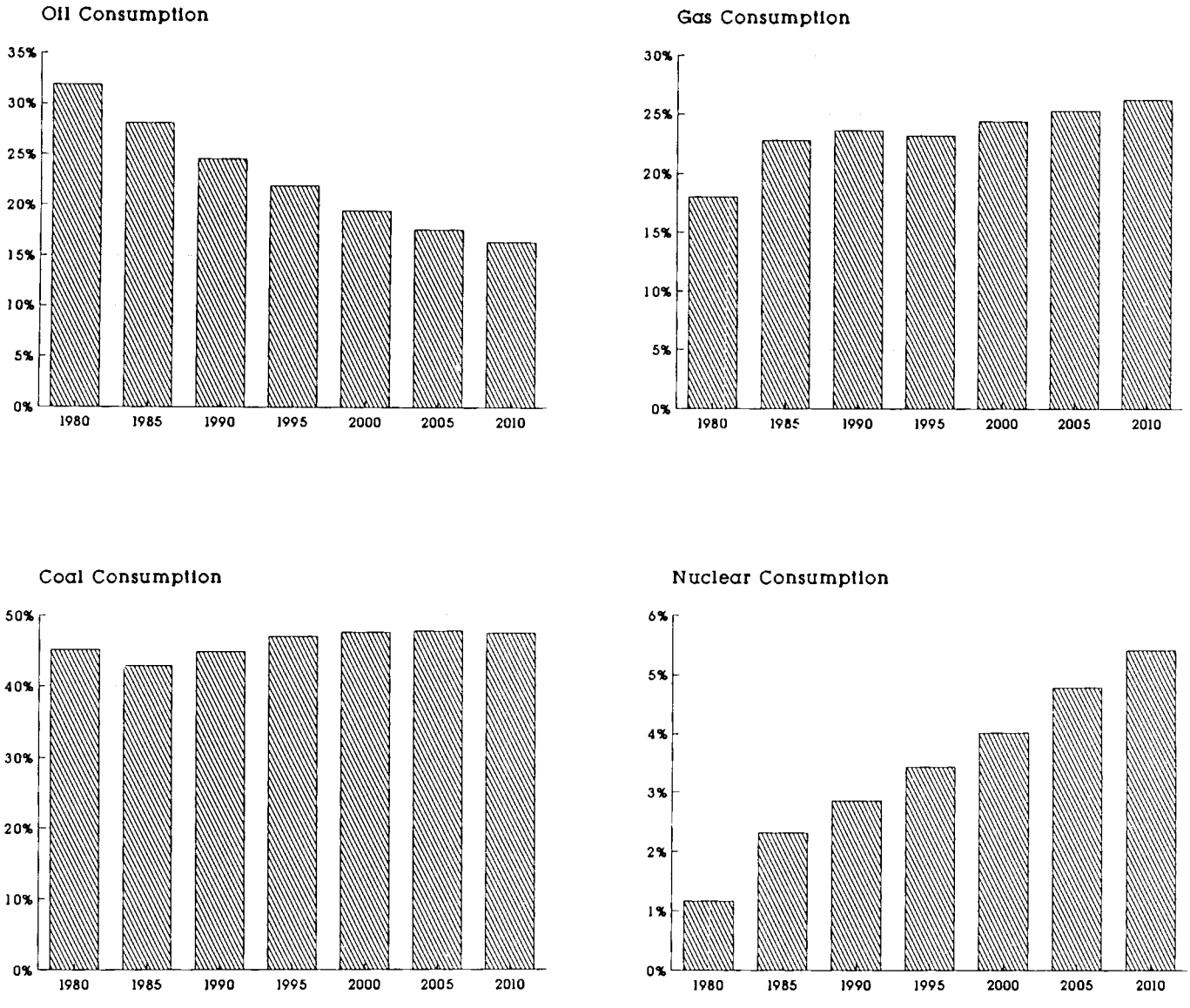
Source: See Appendix D.

Figure 24. CPE Regional Energy/GDP Ratio



Source: See Appendix D.

Figure 25. CPE Total Energy Consumption by Energy Source (Percent)



Source: See Appendix D.

Comparison of International Energy Projections

Projections of world energy markets from different analysts may differ for many reasons. The variations may arise in underlying assumptions concerning key determinants of supply and demand such as future world oil prices and economic growth rates, or differences in definitions, conversion factors, and in the timing of the analysis. The comparisons here sketch out some of the differences between various projections, including comparisons of the EIA base case given in this report with the *International Energy Outlook 1989* and with other widely used energy projections.

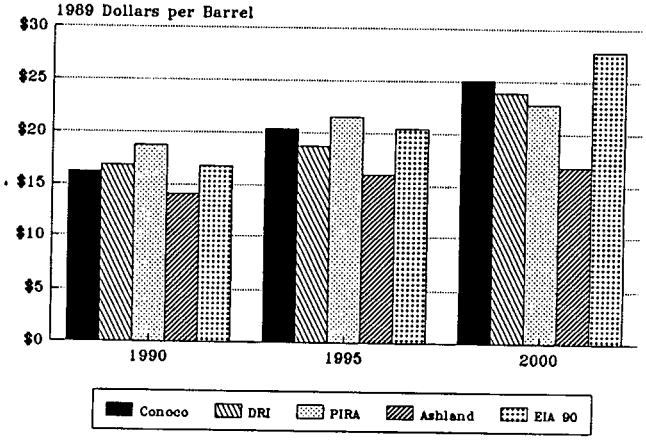
One of the most significant differences between this year's EIA base case and last year's analysis is that non-OPEC oil production for 2000 is projected to be higher than previously projected (Table 1), while OPEC production is projected to be lower. World oil prices for 2000 are currently projected to range from $19.80 to $33.90 per barrel, compared with a higher range of $22.60 to $36.50 per barrel in last year's report (in constant 1989 dollars). As a result, both total petroleum consumption and energy consumption are projected to be higher than in last year's *Outlook*. In addition to the general effects of lower world oil prices on all regions, there are two specific factors which affect the projected consumption for Japan and the LDCs in particular. In Japan, the current projection for oil consumption is higher than in the 1989 *Outlook* because of the more rapid increases in consumption now expected for 1989-1990. The higher LDC forecast for consumption reflects the substantial upward revisions made in estimated historical consumption levels for 1988-1989.

The comparison between the EIA base case and alternative projections shown in Table 2 indicates that these energy projections are generally consistent with most projections, varying by plus or minus 10 percent from the middle of each range. However, there are two categories for which there is wide disagreement. Estimates of the amount of oil available to the Market Economies from the Centrally Planned Economies vary widely, ranging from 1.8 million barrels per day to -1.9 million barrels per day in 2000. This variation is not surprising given the limited information available about events in those countries and the vast potential for change in the Soviet Bloc following the advent of perestroika. EIA's estimate of 1.5 million barrels per day for 2000 is among the more optimistic.

World oil price projections also vary widely, ranging from Ashland's low of $16.90 per barrel in 2000 to EIA's high of $27.80 per barrel (Figure 26). Given the wide range of prices that occurred in the past decade, it is not unexpected that projections vary widely as well. The projections given here represent the midpoint of price ranges from each source, and are presented this way for convenience. The ranges themselves tend to overlap.

The projection for which there was most agreement was U.S. consumption, where the highest estimate was less than 8 percent above the lowest projection. U.S. production estimates, on the other hand, varied by twice as much, with EIA's production estimate the most optimistic for 2000.

Figure 26. Comparison of World Oil Price Projections



Source: See Appendix D.

Table 1. Comparison of Energy and Oil Projections from the International Energy Outlook for the Market Economies: Base Case, 2000

Energy Sources/Regions	Projections for 2000	
	IEO-1989	IEO-1990
Energy Consumption (quadrillion btu)		
United States[a]	90.6	97.4
Japan	20.7	21.0
OECD Europe	68.5	66.0
Other Countries	94.2	91.2
Total	274.0	275.6
Petroleum Consumption (million barrels per day)		
United States	18.6	18.8
Japan	4.7	5.7
OECD Europe	12.4	12.4
Other Countries	19.2	20.1
Total	54.9	57.0
Stock Change and Discrepancy	-0.3	-0.3
Petroleum Supply (million barrels per day)		
OPEC	29.0	28.5
United States	8.5	8.7
Other Non-OPEC	15.6	18.0
Total Production	53.1	55.2
Net CPE Exports	1.5	1.5
Total Available Supply	54.6	56.7

[a] Geographic coverage is the 50 States and the District of Columbia. U.S. Territories are included in "Other Countries."

CPE = Centrally Planned Economies.

OECD = Organization for Economic Cooperation and Development.

OPEC = Organization of Petroleum Exporting Countries.

Note: Totals may not equal sum of components because of independent rounding.

Source: Energy Information Administration, International Energy Outlook 1989, DOE/EIA-0484(89) (1989).

Table 2. Comparison of Energy Projections for the Market Economies, 1990 and 2000 (Million Barrels per Day of Oil Equivalent)

Projection	Consumption			Petroleum Supply					World Oil Prices
	Energy	Total Oil	U.S. Oil	OPEC Production	OPEC Capacity	Non-OPEC	CPE	U.S.	
1989 Estimate	109.9	51.9	17.3	23.4	29.4	26.7	2.3	10.0	$17.70
Projections for 1990									
1990 EIA	112.7	53.0	17.4	23.7	30.6	27.3	2.2	9.7	16.80
Ashland	111.3	50.9	17.4	23.3	30.0	25.5	2.2	[a]9.3	14.10
Conoco	112.4	51.0	17.3	[a]20.8	N/A	[b]30.5	N/A	[a]9.4	16.20
DRI	N/A	52.3	17.3	23.1	[c]29.2	26.3	2.2	9.5	16.90
PIRA	115.0	53.2	17.4	24.0	[c]28.9	27.9	1.8	9.1	[d]18.80
E-W Center	N/A	51.7	17.3	[e]19.8	30.2	[f]29.6	[g]2.3	9.4	N/A
Projections for 2000									
1990 EIA	129.9	57.0	18.8	28.5	34.4	26.7	1.5	8.7	27.80
Ashland	131.8	54.5	18.1	29.8	35.0	23.0	1.8	[a]8.4	16.90
Conoco	136.7	59.5	19.5	[a]29.8	N/A	[b]30.0	N/A	[a]7.6	25.00
DRI	N/A	57.2	19.3	30.1	[c]34.1	25.4	0.9	8.1	23.90
PIRA	140.9	61.0	19.4	32.6	[c]37.2	27.8	0.8	7.4	[d]22.80
E-W Center	N/A	58.6	19.1	[e]32.6	36.8	[f]27.8	[g]1.9	[h]8.5	N/A

[a] Crude oil and natural gas liquids only.
[b] Includes net CPE exports.
[c] Crude oil only.
[d] Price for West Texas Intermediate Crude Oil.
[e] Demand minus non-OPEC capacity.
[f] Non-OPEC Capacity.
[g] Production Capacity minus demand.
[h] Production Capacity.
N/A = Not available.
OPEC = Organization of Petroleum Exporting Countries.
CPE = Centrally Planned Economies.

Sources: **Ashland Oil:** World Energy Outlook Through 2000 **(July, 1989).** **Conoco:** World Energy Outlook Through 2000 **(1989).** **Data Resources, Inc.:** International Oil Bulletin **(Autumn, 1989).** **Petroleum Industry Research Associates:** World Energy Forecast **(November, 1989).** **East-West Center:** World Oil and Demand Outlook to 2000 **(October, 1989).**

Appendix A

World Oil Prices and Balance

Table A1. World Oil Prices, 1979-2010
(1989 Dollars per Barrel)

Year	Price Case-1989 Dollars per Barrel		
	Low	Middle	High
1979		$ 34.88	
1980		50.02	
1981		49.86	
1982		42.44	
1983		35.71	
1984		33.86	
1985		30.76	
1986		15.55	
1987		19.49	
1988		15.18	
1989	$17.10	17.70	$18.30
1990	14.40	16.80	19.20
1991	14.40	16.10	20.50
1992	14.40	16.50	21.90
1993	14.30	18.00	23.20
1994	14.30	19.40	24.60
1995	14.30	20.40	25.90
1996	15.40	21.90	27.50
1997	16.50	23.50	29.10
1998	17.60	25.20	30.70
1999	18.70	26.70	32.30
2000	19.80	27.80	33.90
2001	20.60	29.00	35.50
2002	21.40	30.00	37.10
2003	22.30	31.10	38.70
2004	23.10	32.00	40.30
2005	23.90	32.90	41.90
2006	24.30	33.80	43.00
2007	24.70	34.70	44.10
2008	25.10	35.50	45.20
2009	25.50	36.20	46.30
2010	25.90	36.90	47.40

Note: Prices represent the U.S. refiner acquisition cost of imported crude oil.

Source: **History:** Energy Information Administration, Monthly Energy Review, DOE/EIA-0035(89/09) (1989).
Projections: Energy Information Administration, Oil Market Simulation Model, Oil Market Simulation User's Manual, DOE/EIA-MO28(90).

Table A2. World Oil Consumption and Production: Base Case, 1980-2010
(Million Barrels per Day)

Supply and Disposition	History									Projections				
	1980	1981	1982	1983	1984	1985	1986	1987	Preliminary 1988	1989	1990	1995	2000	2010
Market Economies														
Production														
U.S. (50-States)[a]	10.81	10.74	10.78	10.79	11.11	11.19	10.91	10.65	10.47	9.97	9.71	8.97	8.71	7.83
Canada	1.80	1.65	1.62	1.70	1.81	1.85	1.84	1.95	2.04	1.99	1.96	2.03	2.10	2.10
OECD Europe	2.75	2.93	3.29	3.74	4.06	4.25	4.42	4.49	4.44	4.47	4.96	5.29	5.16	4.44
OPEC	27.80	23.76	20.07	18.75	18.81	17.55	19.69	19.85	22.01	23.44	23.68	26.58	28.47	34.05
Other Countries[b]	6.45	7.07	7.73	8.20	8.94	9.51	9.44	9.80	10.11	10.24	10.67	11.06	10.73	10.37
Net CPE Exports	1.24	1.47	1.68	1.83	2.09	1.96	2.19	2.17	2.43	2.30	2.20	1.92	1.53	-0.07
Net Stock Withdrawals														
U.S. (50-States)	-0.09	0.18	0.32	0.25	-0.09	0.22	-0.15	0.04	0.08	-0.03	0.00	0.01	0.03	0.01
U.S. SPR	-0.05	-0.34	-0.17	-0.23	-0.20	-0.12	-0.05	-0.08	-0.05	-0.06	-0.05	-0.05	0.00	0.00
Other Market Economies	-1.35	-0.04	0.66	0.40	-0.09	0.27	0.07	-0.12	-0.40	-0.71	-0.40	0.00	0.00	0.00
Total Supply	49.36	47.43	45.98	45.42	46.43	46.68	48.37	48.74	51.12	51.61	52.73	55.80	56.72	58.73
Consumption														
U.S. (50-States)	17.06	16.06	15.30	15.23	15.73	15.73	16.28	16.66	17.28	17.25	17.41	18.21	18.84	20.32
U.S. Territories	0.39	0.41	0.31	0.28	0.29	0.27	0.24	0.22	0.20	0.21	0.20	0.21	0.22	0.23
Canada	1.87	1.77	1.58	1.45	1.47	1.50	1.51	1.55	1.60	1.67	1.68	1.91	1.96	1.90
Japan	4.96	4.85	4.58	4.40	4.58	4.38	4.44	4.48	4.73	5.01	5.20	5.77	5.65	5.02
Australia and New Zealand	0.68	0.67	0.70	0.68	0.70	0.70	0.71	0.74	0.77	0.80	0.81	0.88	0.91	1.00
OECD Europe	13.63	12.52	12.05	11.77	11.74	11.68	12.10	12.26	12.36	12.54	12.70	12.92	12.43	11.82
Other Market Economies	11.07	11.46	11.76	11.93	12.23	12.43	12.82	13.24	13.80	14.46	15.02	16.21	17.01	18.75
Total Consumption	49.66	47.73	46.28	45.72	46.73	46.68	48.07	49.15	50.74	51.94	53.03	56.10	57.02	59.03
Discrepancy	0.30	0.30	0.30	0.30	0.30	0.00	-0.30	0.40	-0.39	0.33	0.29	0.30	0.30	0.30

Table A2. World Oil Consumption and Production: Base Case, 1980-2010 (Million Barrels per Day) continued

Supply and Disposition	History									Projections				
	1980	1981	1982	1983	1984	1985	1986	1987	Preliminary 1988	1989	1990	1995	2000	2010
Centrally Planned Economies (CPE)														
Production														
China	2.11	2.01	2.05	2.12	2.30	2.51	2.62	2.69	2.73	2.73	2.81	2.82	2.77	2.50
Soviet Union	11.99	12.15	12.23	12.30	12.20	11.99	12.34	12.57	12.55	12.23	12.03	11.56	10.48	8.16
Other	0.46	0.47	0.49	0.50	0.48	0.48	0.48	0.47	0.46	0.47	0.51	0.42	0.35	0.24
Consumption														
China	1.77	1.71	1.66	1.73	1.74	1.78	1.92	2.08	2.13	2.14	2.12	2.11	2.09	2.02
Soviet Union	9.00	8.94	9.08	8.95	8.91	8.95	8.98	9.00	8.86	8.84	8.82	8.50	7.88	7.06
Other	2.71	2.55	2.52	2.46	2.54	2.53	2.49	2.51	2.51	2.36	2.40	2.28	2.10	1.89
World Oil Consumption	63.14	60.93	59.54	58.86	59.92	59.94	61.46	62.73	64.23	65.28	66.37	68.99	69.09	70.00

[a]Geographic converage is the 50 States and the District of Columbia.
[b]Include Australia, New Zealand, and the U.S. Territories.
CPE=Centrally Planned Economies.
OECD=Organization for Economic Cooperation and Development.
OPEC=Organization of Petroleum Exporting Countries.
SPR=Strategic Petroleum Reserve.

Notes: Production includes crude oil, natural gas liquids, refinery gains, hydrogen, and other hydrocarbons. Totals may not equal sum of components because of independent rounding.

Sources: History: Energy Information Administration, International Energy Annual 1988, DOE/EIA-0219(88) and Monthly Energy Review, DOE/EIA-0035(89/09) 1989; Organization for Economic Cooperation and Development/International Energy Agency, Quarterly Oil Statistics Fourth Quarter 1988 (Paris, France, 1989; Petroleum Economics Limited, Quarterly Supply/Demand Outlook (London, England, 1989). **Projections:** Energy Information Administration, Oil Market Simulation Model, Oil Market Simulation Model User's Manual DOE/EIA-MO28(90). Office of Energy Markets and End Use, "International Energy Outlook 1990 memo to The Record" March 30, 1990.

Appendix B

Assumptions

Table B1. Annual Growth Rates of Real Gross Domestic Product (GDP): Base Case, 1970-2010 (Percent)

Country/Region	Average Annual GDP Growth Rates				
	1970-1980	1980-1985	1985-1990	1990-2000	2000-2010
World	3.7	2.2	3.4	2.5	2.4
Market Economies	3.6	2.1	3.3	2.4	2.4
Total OECD	3.1	2.3	3.2	2.3	2.2
United States[a]	2.7	2.6	3.1	2.5	2.3
Canada	4.6	2.9	3.4	2.6	2.4
Japan	4.6	3.9	4.2	2.6	2.3
OECD Europe	3.0	1.6	3.0	2.0	1.9
Developing Countries	5.4	1.3	3.5	2.9	3.0
OPEC	5.9	-2.3	2.0	2.7	3.0
Other	5.2	2.7	4.0	3.0	3.0
Centrally Planned Economies	3.9	2.6	3.7	2.7	2.5
Soviet Union	3.2	2.2	3.5	2.4	2.1
China	NA	10.0	9.2	4.5	4.2

[a]Projected growth rates are of Gross National Product (GNP).
OECD = Organization for Economic Cooperation and Development.
NA = Not available.
Note: Aggregate growth rates are calculated from aggregate real gross domestic product in 1980 dollars at 1980 exchange rates.
Sources: **History:** Wharton Econometric Forecasting Associates, World Economic Service Historical Data, December 1989 (1989). **Projections:** Energy Information Administration, Annual Energy Outlook 1990, DOE/EIA-0383(90) (1990); Wharton Econometric Forecasting Associates, World Economic Outlook (October 1989); GDP/per capita ratios from the Worldwide Integrated Nuclear Evaluation System (WINES89) times population projections from United Nations, World Population Projections 1988 (New York, NY, 1989); Energy Information Administration, Office of Energy Markets and End Use, "International Energy Outlook 1990 Memo to the Record" March 30, 1990.

Table B2. World Crude Oil Reserves and Resources (Billion Barrels)

Region/Selected Countries	Crude Oil Reserves[a]				Total Resources[b]
	Oil and Gas Journal (1/1/89)	World Oil (1/1/89)	FESAP (Various Dates)		U.S. Geological Survey (1/1/85)
North America	87.7	86.8		NA	139.1 - 280.5
Canada	6.8	7.0		NA	15.3 - 62.6
Mexico	54.1	53.0	27.2	(12/81)	45.0 - 105.0
United States	26.8	26.8	[c]30.4	(12/88)	70.4 - 118.4
Central & South America	68.0	69.8		NA	74.6 - 135.6
Ecuador	1.4	1.2	1.2	(12/82)	3.1 - 8.5
Venezuela	58.1	59.8	18.5	(12/78)	53.7 - 81.7
Western Europe	18.5	18.1		NA	45.1 - 78.1
United Kingdom	5.2	4.3	12.6	(12/81)	19.0 - 23.2
Other North Sea	11.9	11.9	7.0	(12/81)	17.7 - 40.7
Other Western Europe	1.4	1.9		NA	5.2 - 14.2
Eastern Europe and Soviet Union	60.8	62.6		NA	130.0 - 274.0
Soviet Union	58.5	60.9		NA	127.0 - 268.0
Middle East	654.0	584.5	419.2		482.9 - 619.9
Iran	92.9	63.0	62.5	(12/81)	71.1 - 95.1
Iraq	100.0	99.0	34.5	(12/81)	65.7 - 130.7
Kuwait[d]	94.5	98.6	95.7	(12/81)	80.8 - 88.3
Qatar	3.2	2.6	7.1	(12/81)	2.0 - 7.0
Saudi Arabia[d]	255.0	257.5	173.2	(12/81)	193.1 - 239.6
United Arab Emirates	98.1	56.3	43.0	(12/81)	48.7 - 58.7
Africa	56.9	58.8		NA	88.5 - 158.5
Algeria	8.4	8.4	10.4	(12/81)	11.8 - 16.3
Egypt	4.3	4.6	2.4	(12/81)	5.7 - 16.7
Gabon	0.7	0.9		NA	5.0 - 7.0
Libya	22.0	22.4	21.0	(12/81)	29.9 - 40.9
Nigeria	16.0	16.0	12.6	(12/75)	23.2 - 37.2
Other Africa	5.5	6.5		NA	12.1 - 36.1
Far East/Oceania	45.1	43.0		NA	84.8 - 210.8
Australia/New Zealand	1.9	2.5		NA	4.3 - 12.5
China	23.6	22.0	23.6	(12/85)	43.6 - 116.6
Indonesia	8.3	8.4	9.5	(12/82)	13.6 - 26.6
Total OPEC	758.6	694.1		NA	602 - 838
Total Market Economies	906.7	838.8		NA	880 - 1,330
World Total	990.6	923.7		NA	1,060 - 1,720

[a]Reserves include proved reserves and indicated additional reserves in this table. Some foreign countries have a less restrictive definition than EIA of proved reserves that are reported to and published by the various trade journals. Resource data include, in addition to reserves, undiscovered recoverable resources and unproven reserves that are inferred or indicated by engineering or geologic evidence.

[b]Includes a probability range from 95 percent to 5 percent of identified reserves and undiscovered resources.

[c]Energy Information Administration figure published separately (see Sources). This figure includes 26.8 billion barrels of proved reserves and 3.6 billion barrels of indicated additional reserves.

[d]Includes 50 percent of the Neutral Zone. Saudi Arabia revised its oil reserves estimate in January 1989.

NA = Not Available.

OPEC = Organization of Petroleum Exporting Countries.

FESAP = Foreign Energy Supply Assessment Program.

Sources: **Oil:** Oil and Gas Journal 86, 52 (December 26, 1988): World Oil 209,2 (August 1989); Energy Information Administration, Foreign Energy Supply Assessment Program Series regional reports, selected issues, and U.S. Crude Oil Natural Gas and Natural Gas Liquids Reserves, DOE/EIA-0216(88) (1989). **All resources:** U.S. Department of Interior, Geological Survey, World Resources of Crude Oil, Natural Gas, Natural Bitumen, and Shale Oil (Assessment as of 1/1/85 in Paper delivered at 12th World Petroleum Congress in 1987).

Table B3. Oil Production Capacity, 1989-2010
(Million Barrels per Day)

Country/Region	Estimated 1989	Projection Ranges			
		1990	1995	2000	2010
United States	10.1	9.7-10.0	8.5- 9.6	7.8- 9.6	7.4- 8.7
Canada	2.0	1.9- 2.1	1.9- 2.1	1.9- 2.3	1.9- 2.3
Mexico	2.9	2.8- 3.0	2.6- 2.9	2.7- 3.1	3.0- 3.4
North Sea	3.8	4.2- 4.5	4.4- 4.9	4.3- 5.0	3.5- 4.3
Other Non-OPEC	8.1	8.1- 8.9	8.0- 9.1	7.6- 9.1	6.7- 8.5
Total Non-OPEC	26.9	27.1-28.0	26.3-27.9	25.6-28.1	23.5-26.0
Algeria	1.2	1.2- 1.2	1.1- 1.2	1.1- 1.2	1.1- 1.4
Ecuador	0.3	0.3- 0.3	0.3- 0.3	0.4- 0.4	0.1- 0.1
Gabon	0.2	0.2- 0.2	0.2- 0.3	0.1- 0.2	0.0- 0.0
Indonesia	1.5	1.5- 1.5	1.5- 1.6	1.4- 1.7	1.5- 1.9
Iran	3.1	3.0- 3.2	3.2- 3.5	3.5- 4.1	4.5- 5.8
Iraq	3.2	3.4- 3.6	3.8- 4.1	5.1- 6.0	5.5- 7.0
Kuwait[a]	2.8	2.8- 3.0	2.8- 3.0	2.8- 3.2	3.2- 4.1
Libya	1.7	1.7- 1.7	1.7- 1.8	1.8- 2.1	2.2- 2.8
Nigeria	1.8	1.8- 1.8	1.6- 1.8	1.5- 1.7	1.5- 1.9
Qatar	0.5	0.5- 0.5	0.5- 0.5	0.5- 0.6	0.6- 0.8
Saudi Arabia[a]	8.3	8.6- 9.0	8.7- 9.4	8.7- 9.8	10.4-13.3
United Arab Emirates	2.3	2.4- 2.4	2.4- 2.6	2.5- 2.9	2.9- 3.8
Venezuela	2.7	2.7- 2.9	2.8- 3.0	3.0- 3.5	3.9- 5.1
Total OPEC	29.4	30.6-31.0	31.4-32.4	33.8-35.8	40.6-44.6
Net CPE Exports.	2.3	2.0- 2.4	1.4- 2.4	0.9- 2.1	-0.7- 0.5
Total Market Economies	58.6	60.0-61.1	59.8-62.0	61.4-64.9	64.8-69.7

[a]Includes 50 percent of Neutral Zone Capacity.
CPE = Centrally Planned Economies.
OPEC = Organization of Petroleum Exporting Countries.
Notes: Capacity is defined as maximum sustainable production capacity adjusted to reflect current operable capacity in selected countries. The range in U.S. production capacity is derived from production estimates from the Annual Energy Outlook 1990 plus surge production estimates of about 100,000 barrels per day. Production includes crude oil, natural gas liquids, refinery gains, hydrogen, and other hydrocarbons. All uncertainty ranges are derived independently and do not necessarily equal totals.
Source: Energy Information Administration, Office of Energy Markets and End Use, "International Energy Outlook 1990 Memo to the Record" March 30, 1990.

Appendix C

World Energy Consumption by Fuel

Table C1. World Oil Consumption, 1987-2010
(Million Barrels per Day)

Country/Region	History		Projections					
			1995		2000		2010	
	1987	1988	Base	Range	Base	Range	Base	Range
United States[a]	16.7	17.3	18.2	17.4- 19.4	18.8	18.1- 20.2	20.3	19.1- 22.4
Canada	1.5	1.6	1.9	1.7- 2.1	2.0	1.5- 2.3	1.9	1.3- 2.4
Japan	4.5	4.7	5.8	5.1- 6.2	5.7	4.5- 6.5	5.0	3.5- 6.4
OECD Europe	12.3	12.4	12.9	11.3- 14.3	12.4	9.7- 14.9	11.8	8.1- 15.6
United Kingdom	1.6	1.7	1.6	1.4- 1.9	1.6	1.2- 2.0	1.5	1.0- 2.1
France	1.8	1.8	2.0	1.8- 2.2	1.9	1.5- 2.2	1.8	1.2- 2.3
West Germany	2.4	2.4	2.8	2.5- 3.0	2.7	2.2- 3.2	2.5	1.9- 3.3
Italy	1.9	1.8	1.9	1.6- 2.0	1.8	1.4- 2.1	1.7	1.2- 2.2
Netherlands	0.7	0.7	0.7	0.6- 0.8	0.7	0.5- 0.8	0.6	0.4- 0.9
Other Europe	3.9	4.0	4.0	3.4- 4.4	3.8	2.9- 4.6	3.7	2.3- 4.8
Other OECD	1.0	1.0	1.1	0.9- 1.2	1.1	0.8- 1.4	1.2	0.9- 1.6
Total OECD	35.9	36.9	39.9	36.4- 43.2	40.0	34.5- 45.3	40.3	32.8- 48.5
OPEC	3.7	3.9	4.4	4.2- 4.8	4.7	4.0- 5.5	5.4	4.2- 6.6
Other Developing Countries	9.5	9.9	11.8	10.5- 12.8	12.3	9.8- 14.4	13.4	9.6- 16.9
Total Market Economies	49.2	50.7	56.1	53.8- 58.3	57.0	53.1- 60.7	59.0	53.5- 65.0
China	2.1	2.1	2.1	2.1- 2.2	2.1	2.1- 2.2	2.0	1.8- 2.2
Soviet Union	9.0	8.9	8.5	8.3- 8.7	7.9	7.5- 8.3	7.1	6.4- 7.8
Other CPE	2.5	2.5	2.3	2.2- 2.3	2.1	2.0- 2.2	1.9	1.7- 2.1
Centrally Planned Economies	13.6	13.5	12.9	12.6- 13.2	12.1	11.5- 12.7	11.0	9.9- 12.1
World Total	62.7	64.2	69.0	66.6- 71.1	69.1	65.1- 73.0	70.0	64.4- 76.1

[a]Geographic coverage is the 50 States and the District of Columbia. U.S. Territories are included in "Other OECD."
OECD = Organization for Economic Cooperation and Development.
OPEC = Organization of Petroleum Exporting Countries.
CPE = Centrally Planned Economies.
Notes: All uncertainty ranges are derived independently and do not necessarily equal totals. Totals may not equal sum of components because of independent rounding.

Sources: **History:** Energy Information Administration, International Energy Annual 1988, DOE/EIA-0219(88); and Monthly Energy Review, DOE/EIA-0035(89/09) (1989). **Projections:** Energy Information Administration, Office of Energy Markets and End Use, "International Energy Outlook 1990 Memo to the Record" March 30, 1990.

Table C2. World Total Energy Consumption by Type, 1987-2010
(Quadrillion Btu)

Energy Source	History		Projections					
			1995		2000		2010	
	1987	1988	Base	Range	Base	Range	Base	Range
Market Economies								
Oil	100.0	103.5	115	110-119	116	108-124	120	109-133
Gas	40.1	41.7	50	48- 54	58	51- 72	65	54- 84
Coal	44.5	45.4	51	48- 55	55	51- 70	65	58- 84
Nuclear	15.0	16.1	19	19- 20	20	20- 21	24	23- 28
Other	20.9	20.5	24	23- 25	27	25- 34	30	26- 37
Total	220.5	227.1	258	255-262	276	268-282	304	291-317
Centrally Planned Economies								
Oil	28.8	28.7	27	26- 28	26	25- 27	23	21- 25
Gas	25.1	26.0	29	28- 30	32	30- 33	37	33- 41
Coal	46.1	47.6	59	57- 61	63	61- 66	68	65- 72
Nuclear	2.7	3.0	4	4- 4	5	5- 5	8	8- 8
Other	4.2	4.3	6	6- 6	6	6- 6	7	7- 8
Total	106.9	109.6	125	123-127	132	129-137	143	136-150
World Total	327.3	336.7	383	377-389	408	397-419	446	427-467

Notes: Energy totals include consumption of biofuels in the United States. All uncertainty ranges are derived independently and do not necessarily add to totals. Totals may not equal sum of components because of independent rounding.

Sources: **History:** Energy Information Administration, International Energy Annual 1988, DOE/EIA-0219(88); and Annual Energy Outlook, DOE/EIA-0383(90) (1990). **Projections:** Energy Information Administration, Office of Energy Markets and End Use, "International Energy Outlook 1990 Memo to the Record" March 30, 1990.

Table C3. World Total Energy Consumption by Region, 1987-2010
(Quadrillion Btu)

Country/Region	History		Projections					
			1995		2000		2010	
	1987	1988	Base	Range	Base	Range	Base	Range
United States[a]	80.6	83.4	91.9	89.7- 94.0	97.4	96.2-100.0	108.4	105.8-112.5
Canada	9.8	10.4	11.6	11.4- 11.9	12.3	11.9- 12.8	13.3	12.5- 14.1
Japan	16.3	16.8	19.6	19.2- 20.1	21.0	20.2- 21.8	22.9	21.4- 24.4
OECD Europe	56.6	57.1	63.2	62.1- 64.4	66.0	63.9- 68.2	69.8	66.1- 73.6
United Kingdom	8.9	9.1	9.8	9.7- 10.0	10.2	9.9- 10.5	10.7	10.1- 11.2
France	8.4	8.4	9.6	9.4- 9.8	10.1	9.8- 10.5	10.9	10.3- 11.6
West Germany	12.4	12.4	13.6	13.4- 13.9	14.2	13.7- 14.6	14.8	14.1- 15.6
Italy	6.6	6.4	7.2	7.0- 7.3	7.6	7.3- 7.8	8.1	7.6- 8.6
Netherlands	3.2	3.2	3.6	3.5- 3.7	3.8	3.7- 3.9	4.0	3.8- 4.2
Other Europe	17.2	17.7	19.4	19.0- 19.7	20.2	19.6- 20.8	21.3	20.2- 22.5
Other OECD	4.4	4.5	5.1	5.0- 5.2	5.5	5.3- 5.7	6.0	5.6- 6.4
Total OECD	167.7	172.2	191.4	189.1-193.1	202.2	198.7-205.9	220.3	214.9-226.9
OPEC	13.5	13.9	16.1	15.7- 16.5	17.6	16.9- 18.4	19.9	18.4- 21.4
Other Developing Countries	39.3	41.0	50.8	49.4- 52.2	55.7	53.2- 58.4	63.4	58.4- 68.6
Total Market Economies	220.5	227.1	258	255- 262	276	268- 282	304	291- 317
China	24.7	25.7	30.8	30.3- 31.2	33.5	33.2- 34.6	37.6	36.7- 39.1
Soviet Union	57.9	59.1	66.9	65.5- 68.3	70.1	67.7- 72.6	74.5	70.2- 79.0
Other CPE	24.3	24.8	27.3	26.7- 27.8	28.6	27.6- 29.5	30.4	28.7- 32.2
Centrally Planned Economies	106.9	109.6	125	123- 127	132	129- 137	143	136- 150
World Total	327.3	336.7	383	377- 389	408	397- 419	446	427- 467

[a]Geographic coverage is the 50 States and the District of Columbia. U.S. Territories are included in "Other OECD."
OECD = Organization for Economic Cooperation and Development.
OPEC = Organization of Petroleum Exporting Countries.
CPE = Centrally Planned Economies.

Notes: Energy totals include consumption of biofuels in the United States. All uncertainty ranges are derived independently and do not necessarily equal totals. Totals may not equal sum of components because of independent rounding.

Sources: **History**: Energy Information Administration, International Energy Annual 1988, DOE/EIA-0219(88); and Annual Energy Outlook, DOE/EIA-0383(90) (1990). **Projections**: Energy Information Administration, Office of Energy Markets and End Use, "International Energy Outlook 1990 Memo to the Record" March 30, 1990.

Table C4. World Natural Gas Consumption, 1987-2010
(Trillion Cubic Feet)

Country/Region	History		Projections					
			1995		2000		2010	
	1987	1988	Base	Range	Base	Range	Base	Range
United States[a]	17.2	18.0	20.7	19.8- 21.4	22.9	21.6- 24.1	22.2	21.2- 23.0
Canada	2.0	2.4	2.5	2.3- 2.9	2.9	2.6- 3.9	3.4	2.9- 4.8
Japan	1.5	1.6	1.6	0.9- 1.6	2.2	1.5- 3.2	4.0	3.0- 5.8
OECD Europe	9.2	8.8	10.9	10.3- 12.9	13.4	10.9- 18.6	15.2	11.9- 21.6
United Kingdom	2.1	2.0	2.4	2.3- 2.7	2.6	2.5- 3.3	2.7	2.5- 3.4
France	1.1	1.0	0.8	0.4- 1.1	1.2	.9- 2.0	1.1	0.6- 2.2
West Germany	2.1	2.1	2.3	2.0- 2.6	2.9	2.6- 3.8	3.3	2.9- 4.5
Italy	1.4	1.3	1.7	1.5- 2.0	1.9	1.7- 2.7	2.3	1.9- 3.2
Netherlands	1.5	1.5	1.9	1.7- 2.0	2.1	1.8- 2.5	2.3	1.9- 2.7
Other Europe	0.9	0.9	1.9	1.3- 2.6	2.7	1.4- 4.3	3.4	2.1- 5.6
Other OECD	0.6	0.6	0.8	0.8- 1.0	0.9	0.8- 1.2	0.9	0.8- 1.3
Total OECD	30.4	31.4	36.5	35.7- 39.1	42.3	37.4- 51.0	45.7	39.8- 56.5
OPEC	4.8	4.9	5.6	5.2- 6.0	6.2	5.7- 7.9	6.9	5.7- 9.0
Other Developing Countries	3.9	4.3	6.6	5.9- 7.8	8.3	7.0- 11.8	11.0	7.7- 16.5
Total Market Economies	39.1	40.7	48.7	46.9- 52.9	56.8	50.1- 70.7	63.6	53.2- 82.0
China	0.5	0.5	0.7	0.6- 0.7	1.0	0.8- 1.1	1.5	1.4- 1.7
Soviet Union	22.5	23.4	26.2	25.5- 26.7	29.1	27.3- 30.5	33.3	29.3- 36.6
Other CPE	3.8	3.8	4.0	3.9- 4.0	4.2	4.1- 4.3	4.9	4.4- 5.3
Centrally Planned Economies	26.7	27.7	30.8	30.1- 31.4	34.3	32.5- 35.9	39.8	35.1- 43.6
World Total	65.8	68.4	79.5	77.0- 84.0	91.1	82.6-106.6	103.3	88.3-125.6

[a]Geographic coverage is the 50 States and the District of Columbia. U.S. Territories are included in "Other OECD."
OECD = Organization for Economic Cooperation and Development.
OPEC = Organization of Petroleum Exporting Countries.
CPE = Centrally Planned Economies.
Notes: All uncertainty ranges are derived independently and do not necessarily equal totals. Totals may not equal sum of components because of independent rounding.
Sources: History: Energy Information Administration, International Energy Annual 1988, DOE/EIA-0219(88); and Monthly Energy Review, DOE/EIA-0035(89/09) (1989). **Projections:** Energy Information Administration, Office of Energy Markets and End Use, "International Energy Outlook 1990 Memo to the Record" March 30, 1990.

Table C5. World Coal Consumption, 1987-2010
(Million Short Tons)

Country/Region	History		Projections					
			1995		2000		2010	
	1987	1988	Base	Range	Base	Range	Base	Range
United States[a]	837	884	984	974- 988	1,049	1,039-1,059	1,388	1,296-1,446
Canada	54	60	62	58- 68	68	63- 91	75	68- 105
Japan	127	125	127	81- 189	134	86- 239	139	92- 250
OECD Europe	610	609	689	632- 770	741	676- 1007	802	699-1,148
United Kingdom	120	125	139	129- 148	149	138- 194	161	140- 219
France	32	32	26	19- 34	28	21- 44	25	9- 52
West Germany	213	211	225	205- 244	233	220- 302	261	234- 357
Italy	26	25	36	28- 45	41	32- 64	43	32- 69
Netherlands	12	11	16	14- 18	18	16- 25	21	17- 28
Other Europe	207	205	248	235- 280	272	249- 378	291	264- 423
Other OECD	96	99	109	100- 118	121	105- 168	126	100- 187
Total OECD	1,725	1,776	1,971	1,845-2,128	2,113	1,969-2,564	2,529	2,252-3,136
OPEC	7	7	13	8- 17	19	9- 34	25	10- 50
Other Developing Countries	513	516	603	565- 649	669	626- 967	740	679-1,056
Total Market Economies	2,245	2,299	2,588	2,418-2,793	2,801	2,604-3,565	3,294	2,941-4,242
China	1,011	1,054	1,284	1,261-1,299	1,405	1,391-1,456	1,585	1,545-1,651
Soviet Union	804	822	1,089	1,040-1,140	1,132	1,070-1,195	1,150	1,081-1,221
Other CPE	1,018	1,046	1,223	1,189-1,257	1,304	1,249-1,360	1,380	1,296-1,467
Centrally Planned Economies	2,833	2,922	3,596	3,490-3,696	3,841	3,710-4,011	4,115	3,922-4,339
World Total	5,078	5,221	6,184	5,908-6,489	6,642	6,314-7,576	7,409	6,863-8,581

[a]Geographic coverage is the 50 States and the District of Columbia. U.S. Territories are included in "Other OECD."
OECD = Organization for Economic Cooperation and Development.
OPEC = Organization of Petroleum Exporting Countries.
CPE = Centrally Planned Economies.
Notes: All uncertainty ranges are derived independently and do not necessarily equal totals. Totals may not equal sum of components because of independent rounding.
Sources: **History:** Energy Information Administration, International Energy Annual 1988, DOE/EIA-0219(88); and Monthly Energy Review, DOE/EIA-0035(89/09) (1989). **Projections:** Energy Information Administration, Office of Energy Markets and End Use, "International Energy Outlook 1990 Memo to the Record" March 30, 1990.

Table C6. World Nuclear Energy Consumption, 1987-2010
(Terawatthours)

Country/Region	History		Projections								
			1995			2000			2010		
	1987	1988	Base	Range		Base	Range		Base	Range	
United States[a]	455	527	558	558-	558	572	572-	572	595	595-	595
Canada	73	78	102	102-	102	102	102-	123	127	127-	171
Japan	177	164	217	199-	245	280	254-	285	351	301-	383
OECD Europe	617	652	741	734-	752	757	747-	795	915	886-	1,141
United Kingdom	61	68	81	81-	86	84	84-	92	108	108-	136
France	213	220	287	280-	287	306	299-	312	400	388-	449
West Germany	133	140	151	151-	152	150	150-	153	149	149-	211
Italy	16	19	23	23-	23	32	28-	33	54	43-	59
Netherlands	5	6	6	6-	6	6	6-	6	13	9-	14
Other Europe	188	199	192	192-	199	179	179-	200	191	190-	272
Other OECD	0	0	0	0-	0	0	0-	0	0	0-	0
Total OECD	1,322	1,421	1,618	1,593-	1,657	1,710	1,676-	1,776	1,988	1,909-	2,290
OPEC	0	0	0	0-	0	0	0-	0	0	0-	0
Other Developing Countries	88	89	104	104-	118	119	119-	135	189	188-	285
Total Market Economies	1,410	1,510	1,722	1,697-	1,775	1,829	1,796-	1,912	2,176	2,096-	2,575
China	0	0	12	12-	13	13	13-	14	28	27-	29
Soviet Union	172	199	280	275-	285	358	352-	362	517	510-	522
Other CPE	61	63	78	76-	79	90	89-	91	122	119-	122
Centrally Planned Economies	233	263	370	363-	377	461	454-	467	667	656-	673
World Total	1,643	1,773	2,092	2,060-	2,152	2,290	2,246-	2,380	2,843	2,758-	3,248

[a]Geographic coverage is the 50 States and the District of Columbia. U.S. Territories are included in "Other OECD."
OECD = Organization for Economic Cooperation and Development.
OPEC = Organization of Petroleum Exporting Countries.
CPE = Centrally Planned Economies.
Notes: All uncertainty ranges are derived independently and do not necessarily equal totals. Totals may not equal sum of components because of independent rounding.
Sources: History: Energy Information Administration, International Energy Annual 1988, DOE/EIA-0219(88); and Monthly Energy Review, DOE/EIA-0035(89/09) (1989). Projections: Energy Information Administration, Office of Energy Markets and End Use, "International Energy Outlook 1990 Memo to the Record" March 30, 1990.

Table C7. World Other Energy Consumption, 1987-2010
(Quadrillion Btu)

Country/Region	History		Projections					
			1995		2000		2010	
	1987	1988	Base	Range	Base	Range	Base	Range
United States[a]	7.1	6.1	7.7	7.7- 7.7	8.5	8.5- 8.5	10.3	10.3- 10.3
Canada	2.8	2.8	2.9	2.9- 3.0	3.0	2.9- 3.8	3.2	2.9- 3.9
Japan	0.8	0.9	0.9	0.9- 1.0	1.1	1.0- 1.5	1.5	1.3- 2.0
OECD Europe	4.8	5.0	5.3	5.1- 5.5	5.5	5.2- 7.3	5.9	5.3- 7.7
United Kingdom	0.0	0.0	0.0	0.0- 0.0	0.0	0.0- 0.1	0.1	0.0- 0.1
France	0.7	0.7	0.8	0.7- 0.8	0.8	0.7- 1.0	0.8	0.8- 1.0
West Germany	0.4	0.4	0.4	0.4- 0.4	0.4	0.4- 0.6	0.5	0.4- 0.6
Italy	0.5	0.5	0.5	0.5- 0.5	0.5	0.5- 0.7	0.6	0.5- 0.8
Netherlands	0.0	0.0	0.0	0.0- 0.0	0.0	0.0- 0.0	0.0	0.0- 0.0
Other Europe	3.2	3.4	3.6	3.4- 3.7	3.7	3.5- 4.8	4.0	3.5- 5.2
Other OECD	0.4	0.4	0.4	0.4- 0.5	0.5	0.4- 0.7	0.6	0.4- 0.9
Total OECD	15.9	15.2	17.3	17.0-17.7	18.6	18.0-21.8	21.5	20.2- 24.8
OPEC	0.5	0.5	0.7	0.5- 0.8	0.7	0.5- 1.1	0.9	0.4- 1.5
Other Developing Countries	4.5	4.7	6.4	5.6- 7.3	7.2	5.9-10.6	7.8	6.0- 11.2
Total Market Economies	20.9	20.5	24.4	23.3-25.3	26.5	24.5-33.6	30.2	26.5- 37.4
China	1.0	1.1	1.7	1.6- 1.7	1.8	1.7- 1.9	1.9	1.9- 2.0
Soviet Union	2.2	2.3	2.7	2.6- 2.7	2.8	2.7- 3.0	3.0	2.8- 3.2
Other CPE	0.9	1.0	1.2	1.2- 1.3	1.5	1.4- 1.6	1.7	1.5- 1.9
Centrally Planned Economies	4.2	4.3	5.6	5.4- 5.7	6.1	5.8- 6.4	6.6	6.2- 7.1
World Total	25.1	24.7	30.0	28.7-31.3	32.6	30.3-40.0	36.7	32.7- 44.5

[a]Geographic coverage is the 50 States and the District of Columbia. U.S. Territories are included in "Other OECD." U.S. amounts include biofuels such as wood.

OECD = Organization for Economic Cooperation and Development.

OPEC = Organization of Petroleum Exporting Countries.

CPE = Centrally Planned Economies.

Notes: All uncertainty ranges are derived independently and do not necessarily equal totals. Totals may not equal sum of components because of independent rounding.

Sources: **History:** Energy Information Administration, International Energy Annual 1988, DOE/EIA-0219(88); and Annual Energy Outlook, DOE/EIA-0383(90) (1989). **Projections:** Energy Information Administration, Office of Energy Markets and End Use, "International Energy Outlook 1990 Memo to the Record" March 30, 1990.

Appendix D

References and Sources

References and Sources

Energy Information Administration, *Annual Energy Outlook 1990*, DOE/EIA-0383(90) (Washington, DC, 1990).

Energy Information Administration, *Annual Outlook for Oil and Gas 1989*, DOE/EIA-0517(89) (Washington, DC, June 1989).

Energy Information Administration, *Annual Prospects for World Coal Trade 1989*, DOE/EIA-0363(89) (Washington, DC, 1989).

Energy Information Administration, *Commercial Nuclear Power 1989: Prospects for the United States and the World*, DOE/EIA-0438(89) (Washington, DC, 1989).

Jones, D.W., "Urbanization and Energy Use in Economic Development," *The Energy Journal*, International Association of Energy Economists, (Washington, DC, 1989).

United Nations, *World Population Prospects 1988* (New York, NY, 1989).

Figure ES1. Range of World Oil Prices, 1970-2010
Note: All prices are the cost of imported crude oil to United States refineries.
History: Energy Information Administration, *Annual Energy Review 1988*, DOE/EIA-0384(88); and *Monthly Energy Review*, DOE/EIA-0035(89/09).
Projections: Table A1.

Figure ES2. World Oil Reserves, January 1, 1989
Energy Information Administration, *International Energy Annual 1988*, DOE/EIA-0219(88).

Figure ES3. Energy Consumption/GDP Ratio, 1970-2010
History: Wharton Econometric Forecasting Associates, *World Economic Service Historical Data* (1989); United Nations, *1979 Yearbook of International Statistics* (1981); and Energy Information Administration, *International Energy Annual*, DOE/EIA-0219; and *International Petroleum Annual*, DOE/EIA-0042, selected issues.
Projections: Derived from Tables B1 and C3.

Figure ES4. World Energy Consumption by Region, 1970-2010
History: United Nations, *1979 Yearbook of World Energy Statistics* (1981); and Energy Information Administration, *International Energy Annual*, DOE/EIA-0219; and *International Petroleum Annual*, DOE/EIA-0042, selected issues.
Projections: Table C3.

Figure ES5. World Energy Consumption by Type, 1980-2010
History: Energy Information Administration, *International Energy Annual 1988*, DOE/EIA-0219(88).
Projections: Table C2.

Figure 1. OPEC Oil Production as a Percentage of Oil Demand in the Market Economies, 1973-2010
History: Derived from: Energy Information Administration, *International Energy Annual 1988*, DOE/EIA-0219(88); and *Annual Energy Review 1988*, DOE/EIA-0384(88).
Projections: Table A2.

Figure 2. Total OPEC Oil Export Revenues, 1970-1989
Energy Information Administration, Office of Energy Markets and End Use, "International Energy Outlook 1990 Memo to the Record" March 30, 1990.

Figure 3. World Crude Oil Reserves, January 1, 1989
Energy Information Administration, *International Energy Annual 1988*, DOE/EIA-0219(88).

Figure 4. Non-OPEC Oil Production and Oil Prices, 1979-1988
Energy Information Administration, *International Petroleum Statistics Report*, DOE/EIA-0520(89/10); and *Monthly Energy Review*, DOE/EIA-0035(89/09).

Figure 5. OPEC and Non-OPEC Production as a Share of Oil Demand in the Market Economies, 1979-1988
Derived from: Energy Information Administration, *International Energy Annual 1988*, DOE/EIA-0219(88); and *Monthly Energy Review* , DOE/EIA-0035(89/09).

Figure 6. Oil Production and Proved Reserves in the Market Economies
Energy Information Administration, *International Energy Annual 1988*, DOE/EIA-0219(88); and *Oil and Gas Journal* 86, 52, December 26, 1988.

Figure 7. Estimated Number of Active Rigs in the Market Economies, 1979-1988
Energy Economics Research Limited, *Oil and Energy Trends*, various issues, Energy Information Administration, and *Monthly Energy Review*, DOE/EIA-0035(89/09).

Figure 8. OPEC Production Capacity, 1989
Energy Information Administration, Office of Energy Markets and End Use, "International Energy Outlook 1990 Memo to the Record" March 30, 1990.

Figure 9. OPEC Proved Oil Reserves, January 1, 1989
Energy Information Administration, *International Energy Annual 1988*, DOE/EIA-0219(88).

Figure 10. Market Share of Total OPEC Production, 1970-1988
Energy Information Administration, *International Petroleum Statistics Report*, DOE/EIA-0520(89/10); and *Annual Energy Review*, DOE/EIA-0384(88).

Figure 11. OPEC Production Capacity, 1990-2010
Energy Information Administration, Office of Energy Markets and End Use, "International Energy Outlook 1990 Memo to the Record" March 30, 1990.

Figure 12. Range of World Oil Prices with Hypothetical Supply Disruption
Note: World oil availability cut 9 million barrels per day in 1995 for 6 months.
History: Energy Information Administration, *Monthly Energy Review*, DOE/EIA-0035(89/09).
Projections: Table A1; and Office of Energy Markets and End Use, "International Energy Outlook 1990 Memo to the Record" March 30, 1990.

Figure 13. World Oil Consumption, 1970-2010
History: Energy Information Administration, *International Energy Annual*, DOE/EIA-0219; and *International Petroleum Annual*, DOE/EIA-0042, selected issues.
Projections: Table A2.

Figure 14. World Natural Gas Reserves, January 1, 1989
Energy Information Administration, *International Energy Annual 1988*, DOE/EIA-0219(88).

Figure 15. World Natural Gas Consumption, 1988, 2000, and 2010
History: Energy Information Administration, *International Energy Annual 1988*, DOE/EIA-0219(88); and *Monthly Energy Review*, DOE/EIA-0035(89/09).
Projections: Table C4.

Figure 16. World Coal Consumption, 1988, 2000, and 2010
History: Energy Information Administration, *International Energy Annual 1988*, DOE/EIA-0219(88); and *Monthly Energy Review*, DOE/EIA-0035(89/09).
Projections: Table C5.

Figure 17. World Coal Reserves (Billion Short Tons)
Energy Information Administration, *International Energy Annual 1988*, DOE/EIA-0219(88).

Figure 18. World Nuclear Energy Consumption, 1988, 2000, and 2010
History: Energy Information Administration, *International Energy Annual 1988*, DOE/EIA-0219(88); and *Monthly Energy Review*, DOE/EIA-0035(89/09).
Projections: Table C6.

Figure 19. Nuclear Energy Consumption in OECD Europe, 1988, 2000, and 2010
History: Energy Information Administration, *International Energy Annual 1988*, DOE/EIA-0219(88); and *Monthly Energy Review*, DOE/EIA-0035(89/09).
Projections: Table C6.

Figure 20. CPE GDP and Energy Demand as a Percent of World GDP and Energy Demand
History: Derived from: Wharton Econometric Forecasting Associates, *World Economic Service Historical Data* (1989), and Energy Information Administration, *International Energy Annual 1988*, DOE/EIA-0219(88).
Projections: Derived from: Wharton Econometric Forecasting Associates, *World Economic Outlook* (October 1989); and Tables B1, C3.

Figure 21. CPE Regional Net Exports of Petroleum
History: Energy Information Administration, *International Energy Annual 1988*, DOE/EIA-0219(88).
Projections: Derived from Table A2.

Figure 22. CPE Regional Net Exports of Natural Gas
History: Energy Information Administration, *International Energy Annual 1988*, DOE/EIA-0219(88).
Projections: Energy Information Administration, Office of Energy Markets and End Use, "International Energy Outlook 1990 Memo to the Record" March 30, 1990.

Figure 23. CPE Regional Energy Consumption
History: Energy Information Administration, *International Energy Annual 1988*, DOE/EIA-0219(88).
Projections: Table C3.

Figure 24. CPE Regional Energy/GDP Ratio
History: Wharton Econometric Forecasting Associates, *World Economic Service Historical Data* (1989); and Energy Information Administration, *International Energy Annual 1988*, DOE/EIA-0219(88).
Projections: Derived from Tables B4, C3.

Figure 25. CPE Total Energy Consumption by Energy Source
History: Energy Information Administration, *International Energy Annual 1988*, DOE/EIA-0219(88).
Projections: Table C2.

Figure 26. Comparison of World Oil Price Projections
Projections: Ashland Oil: *World Energy Outlook Through 2000* (July, 1989); **Conoco:** *World Energy Outlook Through 2000* (1989); **Data Resources, Inc.:** *International Oil Bulletin* (Autumn, 1989); **East-West Center:** *World Oil and Demand Outlook to 2000* (October, 1989); **Petroleum Industry Research Associates:** *World Energy Forecast* (November, 1989).

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