



# INTERNATIONAL ENERGY OUTLOOK 1 9 9 2

April 1992



Energy Information Administration

This publication and other Energy Information Administration (EIA) publications may be purchased from the Superintendent of Documents, U.S. Government Printing Office.

**All telephone orders should be directed to:**

U.S. Government Printing Office  
**Farragut Bookstore**  
1510 H Street N.W.  
Washington, DC 20005  
(202) 653-7697  
FAX (202) 376-5055  
9 a.m. to 5 p.m., eastern time, M-F

Superintendent of Documents  
U.S. Government Printing Office  
Washington, DC 20402  
(202) 783-3238  
FAX (202) 512-2233  
8 a.m. to 5 p.m., eastern time, M-F

**All mail orders should be directed to:** U.S. Government Printing Office  
c/o Mellon Bank  
P.O. Box 371954  
Pittsburgh, PA 15250-7954

**Complimentary** subscriptions and single issues are available to certain groups of subscribers, such as public and academic libraries, Federal, State, local, and foreign governments, EIA survey respondents, and the media. For further information, and for answers to questions on energy statistics, please contact EIA's National Energy Information Center. Address, telephone numbers, and hours are as follow:

**National Energy Information Center, EI-231**  
Energy Information Administration  
Forrestal Building, Room 1F-048  
Washington, DC 20585  
(202) 586-8800  
Telecommunications Device for the  
Hearing Impaired Only: (202) 586-1181  
9 a.m. to 5 p.m., eastern time, M-F

Released for Printing: April 8, 1992

## **IMPORTANT NOTICE**

As required by Federal Government regulation, the Energy Information Administration (EIA) is conducting a review of its publications mailing list. If you are on the EIA mailing list, you will receive a renewal notice that you must return to us. If you do not return it by **May 29, 1992**, your name will be removed from the EIA mailing list. If you have any questions, you may call the National Energy Information Center at 202/586-8800 between 9 a.m. and 5 p.m., eastern time, Monday through Friday.

**Note: This notice does not apply to paid subscription lists maintained by the U.S. Government Printing Office.**

# International Energy Outlook 1992

April 1992

**Energy Information Administration**  
Office of Integrated Analysis and Forecasting  
U.S. Department of Energy  
Washington, DC 20585

This report was prepared by the Energy Information Administration, the independent statistical and analytical agency within the Department of Energy. The information contained herein should not be construed as advocating or reflecting any policy position of the Department of Energy or any other organization.

## Contacts

The *International Energy Outlook* is prepared by the Energy Information Administration (EIA). General questions concerning the contents of the report may be referred to L.A. Pettis (202/ 586-6351), Acting Director, Office of Integrated Analysis and Forecasting; Mark E. Rodekoher (202/586-1130), Director, Energy Demand and

Integration Division; or Gerald E. Peabody (202/586-1458), Chief of the International, Economic, and Integrated Forecasting Branch. Specific questions about the report may be referred to the authors, A. David Sandoval (202/586-6581), Erik Kreil (202/586-6573), and Lowell S. Feld (202/586-9502).

## Preface

This report presents the current Energy Information Administration (EIA) assessment of the long-term outlook for international energy markets. The 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 U.S. Government policies and foreign government policies are assumed to hold over the projection interval, which extends to the year 2010.

The historic political and economic changes occurring in Eastern Europe and the former Soviet Union will, no doubt, transform regional markets and world trade. This report pays particular attention to energy markets and resources in those countries that were once a part of the Centrally Planned Economies (CPE's) and how prospective changes in these countries might influence the energy outlook for the rest of the world. Projections of world oil prices presented here are consistent with a relatively wide range of prospective futures for the CPE's. These price projections are also used as assumptions for analyses of the U.S. domestic energy market provided in EIA's *Annual Energy Outlook 1992*. In turn, the domestic projections shown here are the same as those contained in the *Annual Energy Outlook 1992*.

Several major EIA estimates determine, in large part, the resulting energy projections presented here. These include estimates of the energy intensity of economic activity; oil and natural gas production capacities; nuclear and hydroelectric generation capacities; international coal trade; and the rate of incremental energy requirements met by alternatives to oil. Uncertainty associated with any projection, frequently conveyed by a set of scenarios or cases, is conveyed here by a set of ranges around a base case. Projected

uncertainty ranges for world oil prices and energy consumption are derived by altering baseline assumptions concerning economic growth, energy demands, and energy supplies. First, the impacts of the variations are estimated individually. Second, a procedure is used that generates a combined range of uncertainty that is greater than any single impact but less than the impact of all changes taken simultaneously (See Appendix A). The result is a base case and a corresponding set of uncertainty ranges, rather than a set of alternative scenarios.

Projections for the United States presented here and in the *Annual Energy Outlook 1992* were prepared using the Intermediate Future Forecasting System (IFFS). Projections of foreign oil production and consumption, and prices of world oil were prepared using the Oil Market Simulation (OMS) Model. Assumptions about total energy requirements of projected economic growth (energy/GDP ratios) and about marginal changes in the makeup of that total (fuel shares) are incorporated in the World Energy Projection System (WEPS) spreadsheet. Assumptions concerning primary electricity requirements (nuclear and hydroelectricity), including generating capacity, capacity utilization factors, and export adjustments, are also included in WEPS. Projections of foreign nuclear power consumption are based on capacity figures in EIA's *Commercial Nuclear Power 1991: Prospects for the United States and the World*. Projections of foreign gross domestic product (GDP) are from Wharton Econometric Forecasting Associates' *World Economic Outlook* (Philadelphia, PA, January and October 1991). Inquiries concerning the availability of EIA reports and models should be directed to EIA's National Energy Information Center (202/586-8800).

# Contents

	Page
Executive Summary .....	vii
World Oil Market .....	1
Long-Term Price Trends .....	1
World Oil Consumption .....	3
OPEC .....	3
Energy Vulnerability .....	4
Iraqi and Kuwaiti Production .....	5
Non-OPEC Production Potential .....	6
Trends in Refining Capacity .....	7
Comparison of International Oil Projections .....	7
World Energy Consumption .....	17
Energy Intensity .....	18
Prospects for Natural Gas .....	19
Prospects for Coal .....	21
Nuclear and Other Energy Sources .....	22
Environmental Considerations .....	24
The Centrally Planned Economies .....	33
Oil Production .....	33
Oil Demand .....	35
Oil Trade .....	35
Natural Gas Overview .....	35
Coal Overview .....	37
Former Soviet Republics .....	38
References .....	45
Appendix	
A. Analytical Methods .....	49

## Tables

1. World Oil Prices, 1979-2010 .....	9
2. World Oil Consumption and Production: Base Case .....	10
3. World Oil Consumption .....	11
4. World Oil Production Capacity Assumptions .....	12
5. Annual Growth Rates of Real Gross Domestic Product (GDP): Base Case .....	13
6. World Crude Oil Reserves .....	14
7. Comparison of World Oil Projections .....	15
8. World Total Energy Consumption by Type .....	27
9. World Total Energy Consumption by Region .....	28
10. World Natural Gas Consumption .....	29
11. World Coal Consumption .....	30

12.	World Net Nuclear Energy Consumption . . . . .	31
13.	World Hydropower and Geothermal Energy Consumption . . . . .	32
14.	Relative Energy Importance of the Republics, 1990 . . . . .	43

## Figures

1.	Persian Gulf Oil Production as a Percentage of World Oil Consumption, 1973-2010 . . . . .	1
2.	World Oil Consumption, 1980-2010 . . . . .	3
3.	Vulnerability of Market Economies to Oil Supply Disruption, 1973-2010 . . . . .	4
4.	World Energy Consumption by Region, 1980-2010 . . . . .	17
5.	World Energy Consumption by Type, 1980-2010 . . . . .	17
6.	Energy Consumption per GDP Ratio, 1980-2010 . . . . .	18
7.	World Natural Gas Consumption, 1980-2010 . . . . .	19
8.	World Coal Consumption, 1980-2010 . . . . .	21
9.	World Coal Reserves . . . . .	22
10.	World Nuclear Energy Consumption, 1980-2010 . . . . .	23
11.	World Carbon Emissions by Fuel Type, 1980-2010 . . . . .	25
12.	Carbon Emissions by Region, 1980-2010 . . . . .	25
13.	CPE Regional Net Exports of Petroleum, 1985-2010 . . . . .	33
14.	CPE Regional Net Exports of Natural Gas, 1985-2010 . . . . .	34
15.	Soviet Oil Exports by Destination, 1990 . . . . .	36
16.	Soviet Oil Exports by Quarter, 1989-1991 . . . . .	36
17.	The Former Soviet Union . . . . .	39
18.	Soviet Energy Trade by Republic, 1990 . . . . .	40

## Executive Summary

Unprecedented political and economic changes are occurring in Eastern Europe and the former Soviet Union.<sup>1</sup> The energy sectors in these “economies in transition” are generally highly inefficient both in terms of energy production and energy use. Energy has been highly subsidized within these countries, resulting in inadequate investments to bring about efficiency gains characteristic of the free market economies in recent years.

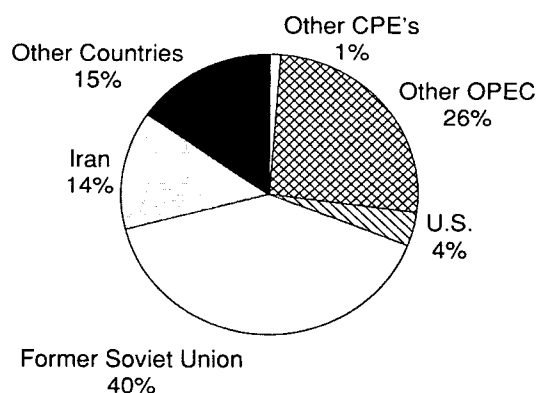
No doubt the changes and reforms in those countries that were once a part of the Centrally Planned Economies (CPE's) will have a strong influence on prospects for their energy sectors. For example, energy prices are already increasing substantially in many of these countries; Russia is already demanding hard currency for its energy exports; and Eastern European countries are already shopping for energy imports on the world market. The ability of the CPE's to transform from command to market economies will be affected by how well their energy sectors function over the transition period. More important to the United States is the fact that these changes and reforms in the evolving CPE's will help mold energy prospects not only in the CPE's but also in the world as a whole, reflecting the fact that most energy markets are worldwide. This potential to influence world energy trends results from the vastness of the resources and economies involved and from the growing importance of world trade—not to mention the broader question of world political stability.

The former, evolving, and current CPE's, henceforth called simply the CPE's, already command a large share of the world's total energy supplies. In 1990, for example, they accounted for almost one-third of all energy consumed (excluding non-commercial biofuels such as wood used extensively in many parts of the world). By comparison, the United States consumed about one-quarter of the 1990 total. Barring a major political or economic collapse, the CPE's are expected to account for about the same proportion of total world energy consumed over the entire projection period, to

the year 2010. In contrast, the U.S share of world energy consumption declines moderately over this period.

The potential influence of the CPE's on world energy markets is indicated by the share of world energy reserves contained within their borders. In terms of world trade, possibly the most important energy resource available in abundance to the former Soviet Union is natural gas (Figure ES1). Not only Eastern Europe but also Western Europe will require substantial imports of natural gas in order to meet demand expectations. Much, but not all, of these imports will likely come from the former Soviet Union.

**Figure ES1. World Natural Gas Reserves, January 1, 1992**



Total = 4,378 Trillion Cubic Feet

Note: CPE's include former, evolving, and current Centrally Planned Economies.

Source: *Oil and Gas Journal*, December 30, 1991, pp. 48-49.

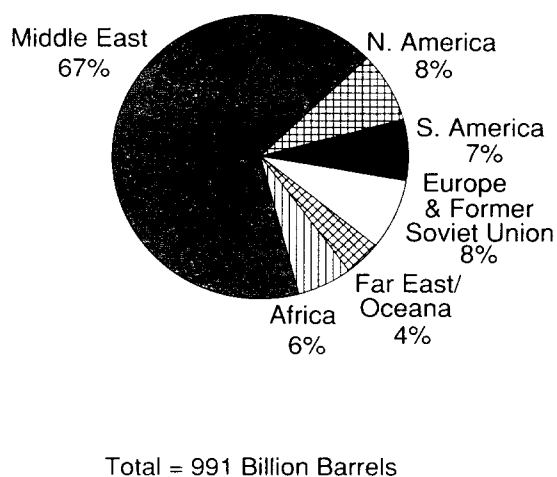
<sup>1</sup>The historical data and projections presented in this report for the region called the former Soviet Union include the 11 republics of the newly created Commonwealth of Independent States, the 3 newly independent Baltic States, and the republic of Georgia, which has not yet joined the Commonwealth.



Within the CPE's, except in the former Soviet Union, coal is and will continue to be the most important energy source. This is particularly true in China, where coal accounts for about three-quarters of all energy consumed, again excluding non-commercial biofuels. Coal will continue to maintain this relative importance in China through the year 2010. Coal is the dominant source of energy in Eastern Europe as well, accounting for about half of all energy consumed in 1990. Coal consumption in Eastern Europe should remain flat through 2010, however, as natural gas grows in importance.

The CPE's will have a modest impact on prospects for the world oil market because they have a relatively small portion of the world's oil reserves (Figure ES2). Oil reserves in the former Soviet Union are estimated to be about equal to those in Mexico and Canada combined, but are dwarfed by the oil reserves in the Middle East. While the former Soviet Union is currently a major producer and exporter of oil, it will find it increasingly difficult to meet domestic needs in the future.

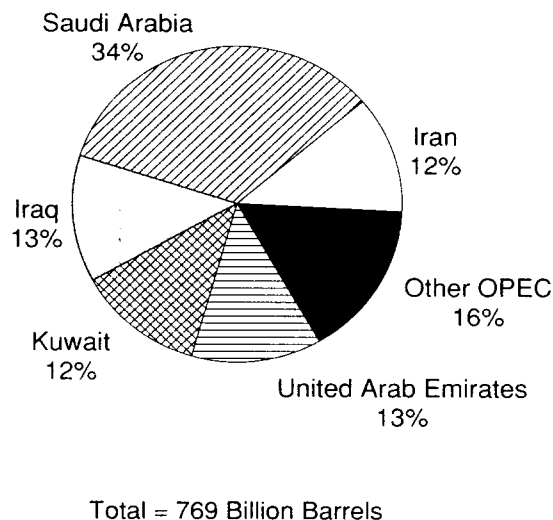
**Figure ES2. World Oil Reserves, January 1, 1992**



Source: *Oil and Gas Journal*, December 30, 1991, pp. 48-49.

The Middle East is and will continue to be the dominant region of the world with respect to oil. Middle East (Persian Gulf) oil producers dominate the Organization of Petroleum Exporting Countries (OPEC) (Figure ES3). Oil will continue to be the world's most important energy source, even though world natural

**Figure ES3. OPEC Proved Oil Reserves, January 1, 1992**



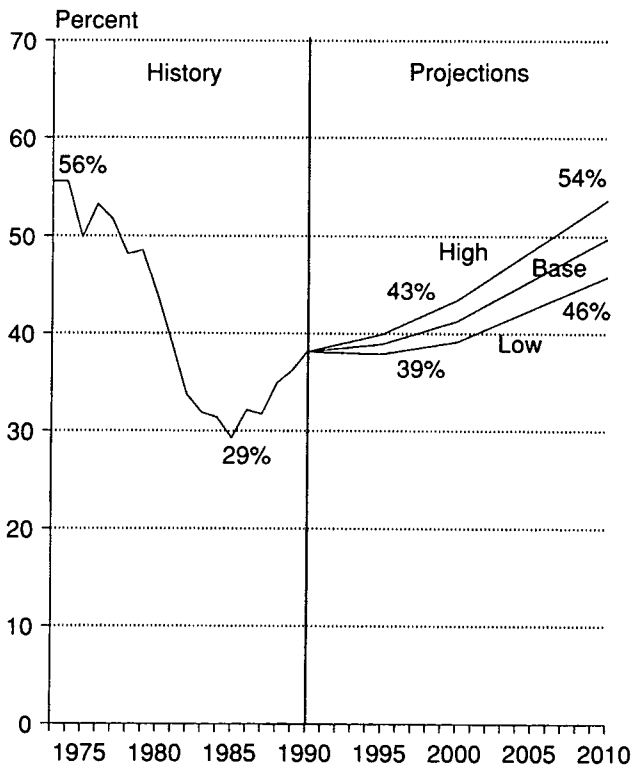
Source: *Oil and Gas Journal*, December 30, 1991, pp. 48-49.

gas consumption will grow much faster than world oil consumption between now and 2010. Growth in natural gas consumption could average about 2 percent per year over this period compared with about 1.2 percent per year for oil and about 1.6 percent for total energy.

Reflecting the distribution of world oil reserves, oil produced by OPEC accounts for over one-third of all oil consumed in the world. By 2010, OPEC could easily produce half of all the oil consumed in the world (Figure ES4). This prospect is possible because OPEC members, especially the Persian Gulf members, control such a huge share of the world's high-quality low-cost oil reserves. The concentration of oil reserves in OPEC; the willingness and ability of OPEC to expand production capacity, including production potential from Kuwait and Iraq; and the limited ability of non-OPEC oil producers to expand production capacity are the major factors on the supply side that will influence prospects for world oil prices.

World oil prices (expressed in 1990 dollars per barrel and defined as the average refiner acquisition cost of imported crude oil in the United States) are expected to remain well below the post oil-shock highs that occurred in 1980 and 1981 between now and 2010 (Figure ES5). In this report (*IEO92*), prices in 2010 are projected to range between \$23 and \$40 per barrel. The base case, at \$33 per barrel in 2010, is not presented as

**Figure ES4. OPEC Oil Production Percentage of World Oil Consumption, 1973-2010**

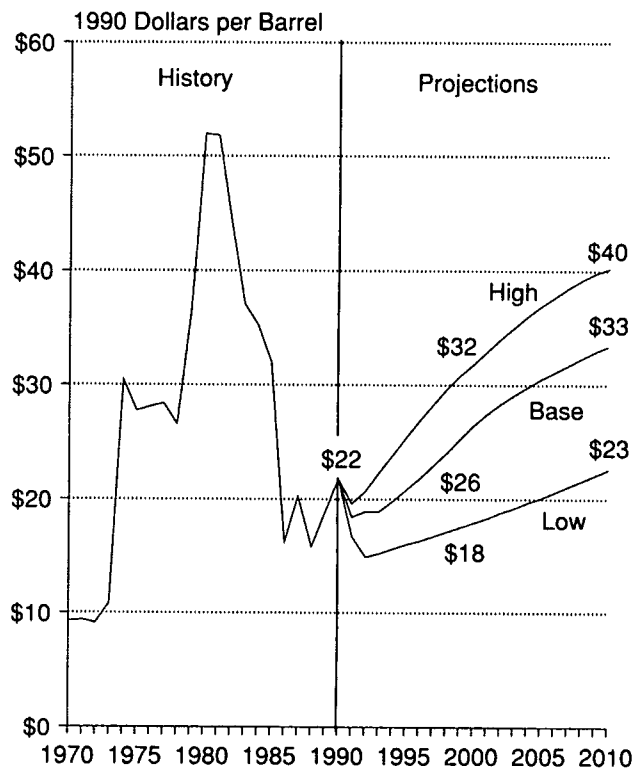


Sources: **History:** Energy Information Administration, *International Energy Annual 1990*, DOE/EIA-0219(90); and *Annual Energy Review 1990*, DOE/EIA-0384(90). **Projections:** Production levels from Table 2 and derived from Table 4, divided by world consumption from Table 2.

a most likely case, but simply as a representative case. Absent a politically caused supply disruption, oil prices in real terms remain relatively stable through the mid-1990's before rising steadily thereafter. This general pattern assumes that the demand for oil will continue to rise, spurred primarily by world economic growth. Eventually, OPEC surplus production capacity is reduced and prices rise to balance demand and supply. Additional factors that will influence world oil balances and prices include gains in energy conservation and efficiency, fuel switching, and non-OPEC production capabilities, including those in the former Soviet Union.

The expected growth in world economic activity will require increased use of all other energy sources in addition to oil. World economic growth, as measured by gross domestic product (GDP), is projected to average about 3 percent per year between 1990 and 2010. An important assumption used in this report is

**Figure ES5. Range of World Oil Prices, 1973-2010**



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

Sources: **History:** Energy Information Administration, *Annual Energy Review 1990*, DOE/EIA-0384(90); and *Monthly Energy Review*, DOE/EIA-0035(91/12). **Projections:** Table 1.

that world energy consumption grows about half as fast as world GDP over the same time interval. The lower rate of growth for energy consumption is dependent upon continued success in improving energy conservation and efficiency. An implicit assumption is that technological innovation will play a large part in these efforts. Energy growth will also be lower than economic growth as a result of a restructuring of economies away from more energy-intensive activities to less energy-intensive activities. Very important in all of these energy-saving activities will be the international transfer of technology and managerial skills and the international flow of investment capital. International cooperation will also be a key element in the growing struggle to balance energy use in the pursuit of economic prosperity with environmental integrity. Current country policies and international treaties are assumed to hold over the entire projection period.

# World Oil Market

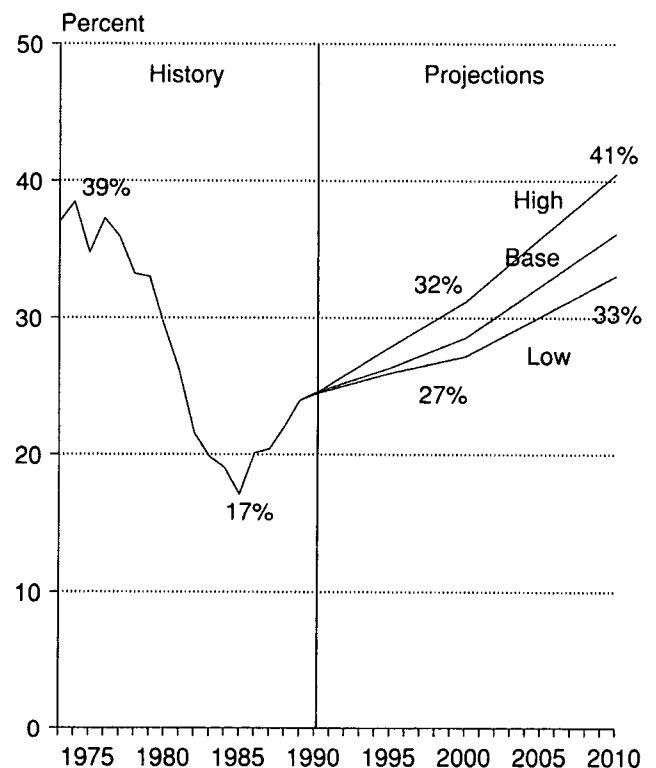
## Long-Term Price Trends

Beyond the mid-1990's, oil prices are expected to rise despite record levels of non-OPEC production (excluding the former, evolving, and current Centrally Planned Economies, henceforth called simply the CPE's) during this decade (Tables 1 and 2). Over this period world oil demand is expected to increase, especially in the developing countries (Table 3). At the same time, despite a drop in consumption in the former Soviet Union as it makes its transition from a centrally planned economy to independent market economies, production in the new republics is expected to erode even more, reducing the amount of oil available for export. As a result, the world's reliance on oil from OPEC, and particularly from the Persian Gulf, is expected to increase (Figure 1). Unless consuming countries change current energy policies, this trend is expected to continue because OPEC countries, and in particular Persian Gulf members, control the world's largest and least expensive known oil reserves.

Because little surplus production capacity exists outside of OPEC, increases in price will become necessary to balance demand and supply as surplus OPEC capacity declines in the next 5 to 20 years. Many factors will determine when this happens, including changes in demand resulting from economic growth, conservation, fuel substitution, energy policy, and environmental factors. The rate of change in non-OPEC production, political events, the outcome of changes in the CPE's, and events in the OPEC countries will also affect changes in oil prices.

The degree to which oil prices might rise depends largely on OPEC's behavior with respect to capacity expansion. Only OPEC countries, and in particular the Persian Gulf members, can add enough capacity to meet anticipated increases in demand. Market share and revenue goals, as well as political and security considerations, will influence OPEC's production and capacity decisions. The most likely course is that OPEC

Figure 1. Persian Gulf Oil Production as a Percentage of World Oil Consumption, 1973-2010



Sources: **History:** Energy Information Administration, *International Energy Annual 1990*, DOE/EIA-0219(90), and *Annual Energy Review 1990*, DOE/EIA-0384(90). **Projections:** Production levels from Table 2 and derived from Persian Gulf production capacity in Table 4, divided by world consumption from Table 2.

member nations will expand their production capacities and moderate price increases in the future in order to earn more revenue, to gain leverage in OPEC's decisionmaking process, and to maintain market share (Table 4).

## Country Groupings

The *International Energy Outlook 1992 (IEO92)* uses a number of country groupings both in analyzing the current energy picture and in projecting future energy requirements and supply throughout the world. Because of major changes in countries previously termed Centrally Planned Economies, particularly developments in the former Soviet Union, there are some differences in country groupings from previous *IEO's*. This report uses the following country groupings:

**Centrally Planned Economies.** Includes former, evolving, and current Centrally Planned Economies (CPE's) of Albania, Bulgaria, Cambodia, China, Cuba, Czechoslovakia (now called the Czech and Slovak Federal Republic), Hungary, Laos, Mongolia, North Korea, Poland, Romania, the former Soviet Union, Vietnam, and Yugoslavia.

**Former Soviet Union.** Includes the Baltic States of Estonia, Latvia, and Lithuania, as well as Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan.

**Commonwealth of Independent States.** Includes the former Soviet Union less Georgia and less the three Baltic States of Estonia, Latvia, and Lithuania.

**Organization for Economic Cooperation and Development (OECD).** Includes Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States.

**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.

**Market Economies.** Includes all countries other than the CPE countries.

**Developing Countries.** Includes all Market Economy countries other than the OECD countries.

There are major areas of uncertainty in world energy markets. One concerns the outcomes of events in the former Soviet Union; the projections in this *IEO92* consider a wide range of former Soviet Union consumption and production levels. The prices listed in the *IEO92* represent a range judged to be most likely. Price movements outside of the range should trigger market forces which will move prices back inside of the range.

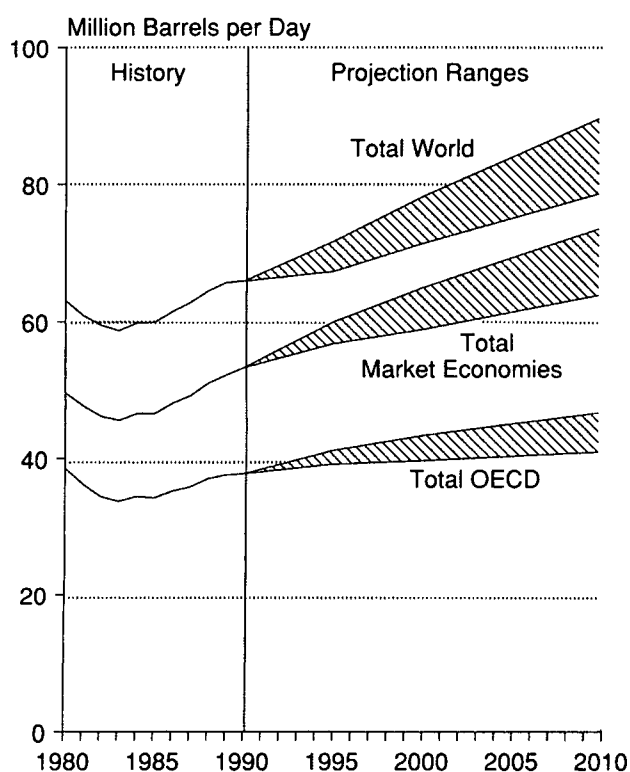
The trajectory of prices in this range is uncertain. Prices could temporarily fluctuate either below or above this range, similar to the pattern between 1970 and 1990. During that period, prices fluctuated between \$10 per barrel and \$50 per barrel in 1990 dollars (i.e., adjusted for inflation). However, the extremes were unsustainable, and for the majority of the time prices

ranged between \$15 per barrel and \$30 per barrel, with \$18 per barrel the average price for 1991. Similarly, prices are expected to remain predominately within the range in this *IEO92*, although temporary movements outside this range should not be unexpected. Prices are expected to range between \$18 per barrel and \$32 per barrel in 2000, and increase to between \$23 per barrel and \$40 per barrel in 2010. The mid-level price path in this *IEO92* does not represent a most likely case and is smooth only for analytical convenience. Such a smooth path is unlikely given the fluctuations in the past. The shape of the price path does make a difference on the future of economic growth, with large fluctuations and price shocks leading to uncertainty and slower growth. The mid-level price case here is just one of many possible paths, each with its own effect on economic growth.

## World Oil Consumption

World oil demand should continue to grow in response to economic growth (Figure 2). Total world oil consumption is expected to grow by a little more than 1 percent per year through 2010, less than the projected annual growth rate in gross domestic product (GDP) of almost 3 percent (Table 5). This rate is considerably less than during the last few years. Total world oil consumption grew by almost 2 percent per year from 1985 to 1990, or about two-thirds as fast as GDP growth.

**Figure 2. World Oil Consumption, 1980-2010**



Sources: *History*: Energy Information Administration, *International Energy Annual 1990*, DOE/EIA-0219(90). *Projections*: Table 3.

The primary reason for continued growth in world oil consumption is that as world economies grow and energy demand increases to fuel that growth, oil will remain the dominant fuel for many uses. The major reason for this conclusion is that neither natural gas nor alternative fuels are expected to displace oil's dominant position in meeting transportation needs. However, growth in world oil demand will be moderated by increases in energy efficiency, conservation, and increased use of other fuels for some applications, such

as natural gas for electric generation. Increases in world oil prices are expected to spur many of these oil-saving activities.

Demand growth will continue to be most rapid in the developing nations of Asia and the Middle East. Consumption growth in the Middle East was 3.7 percent and 5.2 percent in the Far East and Oceania from 1985 to 1990, well above the growth in total world oil consumption. Countries such as China, India, Indonesia, South Korea, Malaysia, Taiwan, and Thailand showed rapid increases in consumption during this time, as did the industrialized nation of Japan. These rates of increase for developing nations are expected to slow considerably, but still be about twice as high as for the rest of the world. However, developing nations have additional restraints on oil demand growth; increases in congestion from population growth, for example, could limit growth in transportation usage. This rapid growth in demand corresponds to the rapid growth in economic activity expected for these nations. GDP growth rates are expected to exceed 4 percent between 1990 and 2010 in the developing nations (Table 5).

## OPEC

Nearly all producing countries inside and outside of OPEC expanded production to offset the loss of oil resulting from the Iraqi invasion of Kuwait and the subsequent economic embargo on Iraq. (See "Iraqi and Kuwaiti Production," p. 5.) As a consequence, several OPEC countries, notably Saudi Arabia, have changed their pre-invasion long-term plans to accelerate and expand sustainable production capacity to meet a growing demand for oil (Table 4). Saudi Arabia has already announced plans to expand its production capacity from 8.5 million barrels per day in 1990 to over 10 million barrels per day by 1995. This expansion is motivated in part by political and security reasons as Saudi Arabia seeks to exert its influence and continue its current role as the dominant producing force in OPEC. In addition, Kuwait and Iraq are still expected to increase their production capacity in the future, although these increases will be delayed from their earlier plans.

The major players in future oil market developments are the countries holding the largest reserves (Table 6). OPEC has three-fourths of the world's proved oil reserves (almost 1 trillion barrels), with a high probability of much more still to be discovered. Within OPEC, Saudi Arabian reserves are over 250 billion barrels, followed by Iraq, the United Arab Emirates,

Kuwait, and Iran with about 100 billion barrels each, and Venezuela, with about 60 billion barrels. The United Arab Emirates include: Ajman, Abu Dhabi, Dubai, Fujairah, Ras al-Khaimah, Sharjah, and Umm al Qaiwain. Overall, the end-of-1991 OPEC reserve levels are the equivalent of over 80 years of crude oil production at 1991 production rates, compared with 7 years for the United States, 8 for the North Sea, and 15 for the former Soviet Union.

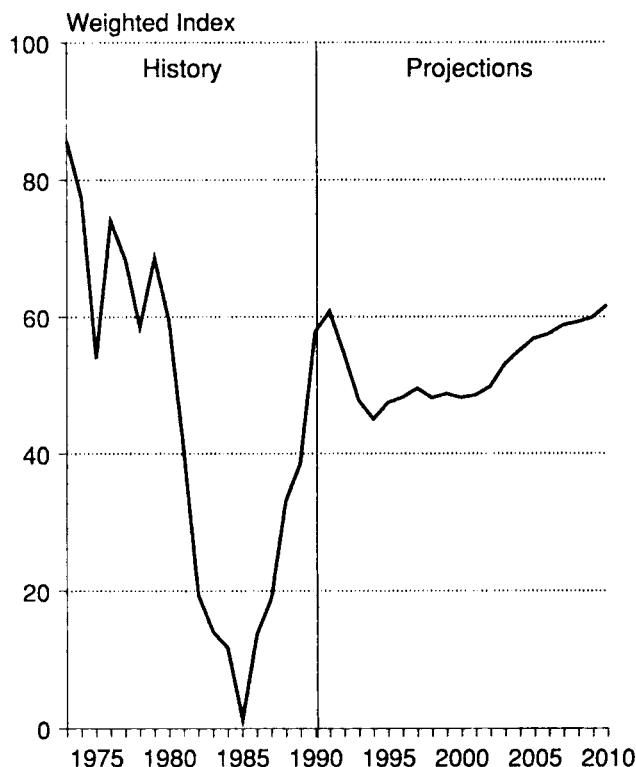
Not all OPEC countries face the same prospects for production and revenues in the future. Several OPEC countries may even become net oil importers (Ecuador, Gabon, Indonesia); several will have to invest in enhanced oil recovery methods (Algeria, Libya, Nigeria); and several will have to expand their export distribution capability (Saudi Arabia, Iraq, Venezuela).

## Energy Vulnerability

The likelihood of another disruption occurring in the Persian Gulf region in the near future has theoretically been reduced by the demise of Iraq's military might. Global dependence on the Persian Gulf for oil supplies, however, is increasing at a fast rate. Two-thirds of the world's oil reserves are located in the Persian Gulf. These reserves are also among the cheapest to produce, with production costs only a few dollars per barrel. In 1989, the Persian Gulf supplied almost one-fourth of the world's oil. By 2010, dependence could increase to 40 percent. At this rate, petroleum exports from the region would nearly double to over 22 to 29 million barrels per day, approximately 1 to 8 million barrels per day above the historic high in 1977 of 21 million barrels per day. Persian Gulf oil and gas will continue to be a leading source of energy supply well into the 21st century.

The vulnerability of the United States and the Market Economies to energy supply disruptions is a complex issue. Vulnerability is not simply a matter of dependence on a particular supply source. Neither is it simply a regional concept. Oil supply vulnerability is a world concept because of the general linkage of world economies and the competition for available supplies. Vulnerability, therefore, can be thought of as a combination of global dependence on a concentrated supply source, the availability of oil supply-disruption offsets such as excess oil production capacity and petroleum stocks, and other factors such as political stability which may influence the security of supplies.

**Figure 3. Vulnerability of Market Economies to Oil Supply Disruption, 1973-2010**



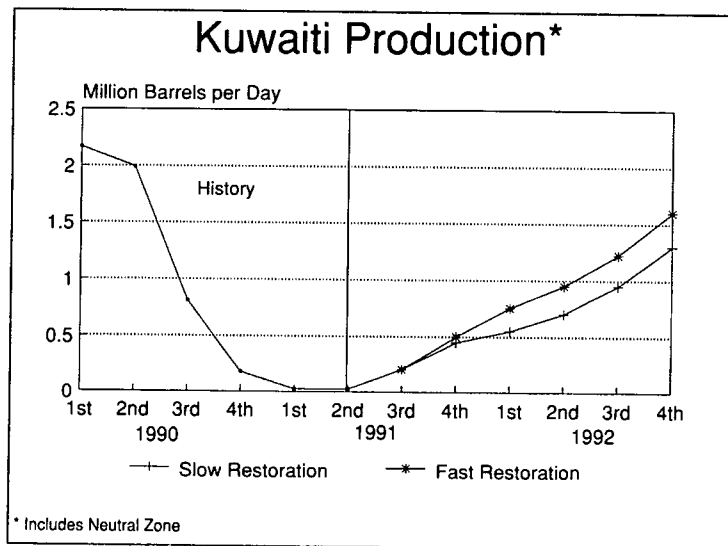
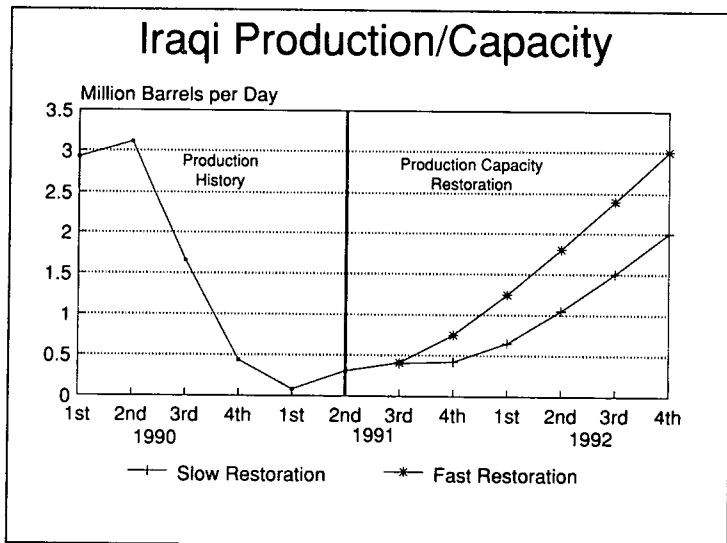
Sources: **History:** Energy Information Administration, *Annual Energy Review 1990*, DOE/EIA-0384(90); and *International Petroleum Statistics Report*, DOE/EIA-0520(92/01). **Projections:** Derived from Tables 2 and 4 and assumptions about growth in overall petroleum demand and planned additions to strategic stocks.

While these complexities make it difficult if not impossible to quantify vulnerability, the index presented in Figure 3 attempts to present an indication of how vulnerable the Market Economies are to potential oil supply disruptions. The index is constructed to show only relative measures of vulnerability. When the index is higher, it indicates that the Market Economies are relatively more vulnerable to large increases in prices as a result of a disruption than when the index is lower. That is, relatively large index values indicate that the probability of experiencing large price increases (and hence greater damage to the economy) is higher than when the index values are relatively low. The projections detailed in this report show an increase in dependence on Persian Gulf oil that serves to reinforce concerns about energy vulnerability. The index characterizes past and future

## Iraqi and Kuwaiti Production

At the end of 1991, Iraq had the capacity to export the United Nations sanctioned \$1.6 billion of oil, roughly equivalent to 500,000 barrels per day, implying a production capacity of around 1 million barrels per day, which is near the fast restoration scenario shown to the right. By the end of 1992, Iraq may be able to produce 2 to 3 million barrels per day at full capacity. This forecast assumes that increases in Kuwaiti production capacity enable Kuwait to produce between 550 and 750,000 barrels per day of oil in the first quarter of 1992. If the embargo is not lifted, then the supplies of oil from Iraq would be substantially less than capacity. The graphs to the right show the range of expected capacity restoration.

This forecast assumes Iraq will produce approximately 400,000 barrels per day and Kuwait (including the Neutral Zone) will produce between 700 and 950,000 barrels per day of oil in the second quarter of 1992. As Kuwait's production increases other producers will need to adjust production or risk more price weakness—especially during this seasonally low demand period.



Source: **History:** Energy Information Administration, *International Petroleum Statistics Report*, DOE/EIA-0520(91/11).

vulnerability, taking into account (1) dependence on Persian Gulf oil (in this case the percent of Market Economy demand supplied by Persian Gulf countries), (2) oil stock levels (in this case the level of stocks at the end of the year in Organization for Economic Cooperation and Development countries, including strategic stocks expressed in terms of days of supply), and (3) excess crude oil production capacity (in this case production capacity in the Organization of Petroleum Exporting Countries minus actual production). The more dependent the Market Economies are on Persian Gulf oil, the more likely that a disruption of supplies from this region would impact world markets. Conversely, high levels of oil stocks, including strategic reserves held by the United States, Japan, and Germany, can be used to counter or limit the impact of a disruption and may even make such an event less likely. The availability of excess crude oil production capacity to counter the effect of a disruption is also critical. For example, during the Persian Gulf War, this excess capacity was quickly used to help counter the impact of the disruption and greatly reduced the economic damage that could have occurred.

Figure 3 summarizes the index for the period 1973 through 2010. The three measures of vulnerability were combined using weighted averages of 50 percent for excess capacity, 30 percent for Persian Gulf dependence, and 20 percent for available stocks. However, it is important to note that since the variables generally follow similar patterns, the use of another weighting scheme would make very little difference (See Appendix A). Regardless of the weighting system used, the message is the same: after enjoying several years of relatively low vulnerability because of high stock levels, low dependence on the Persian Gulf, and high excess capacity, these projections suggest that, if no additional steps are taken by consuming countries to reduce vulnerability, the world will become increasingly vulnerable to supply disruptions and by 2010 will be much closer to the level of vulnerability experienced in the early 1970's.

## Non-OPEC Production Potential

Non-OPEC production (excluding former and current Centrally Planned Economies) is expected to steadily increase until the end of the decade (Table 2). This continues a long-term trend interrupted only in the mid to late 1980's, when production plateaued largely because of a series of accidents in the North Sea and a decline in U.S. production which offset production increases elsewhere. Non-OPEC production has

historically been underpredicted, with more oil being found at a time when it was believed ready to peak and decline. In this *IEO92* base case, production by the end of the decade increases by more than 3 million barrels per day from 1990 levels, then levels off and declines slowly thereafter.

Record production levels expected in the North Sea are a major reason why non-OPEC production should continue to rise. Capacity increases from Norway and, to a lesser extent, the United Kingdom could total about 1 million barrels per day. As a result, North Sea production should not peak until the end of the decade, in contrast to expectations of only a few years ago that these fields should mature and decline by 1995. The primary reasons for the change in expectations include larger-than-anticipated discoveries in the 1980's, discoveries of small fields near existing infrastructure (allowing for easier development), improved oil reservoir management techniques which reduced declines in mature fields, and increased North Sea natural gas production which resulted in additional natural gas liquids and condensate being produced.

Production increases are also expected in the Middle East and Far East. Syria and Yemen are each expected to add several hundred thousand barrels per day of production during the next decade, with Oman holding steady and probably increasing slightly. Oil companies have also increased their efforts in the Far East, resulting in additional forthcoming production from Australia, India, Malaysia, and Papua-New Guinea of perhaps a total of half a million barrels per day by the end of the decade. Additional Far Eastern production is expected to come from the Centrally Planned Economies of China and Vietnam.

In Latin America, Brazil and Mexico together could add another million barrels per day within the decade; Colombia could add more as well. The size of the recently discovered Cusiana field in Colombia has been estimated by some analysts to be between 2 and 5 billion barrels of recoverable crude oil. If these estimates prove correct, it would be the largest discovery in the Western Hemisphere since Prudhoe Bay, Alaska in 1968 and would more than double previous estimates for Colombia of almost 2 billion barrels. Brazilian increases are contingent upon developing their deepwater fields, while Mexican production increases are contingent upon an acceleration of development of their discoveries. In order to do this, additional government investment funds need to be directed to development because foreign companies are not currently allowed to produce in Mexico. Mexico has proved reserves of over



50 billion barrels, about the same magnitude of those in the former Soviet Union, yet Mexican production was only 3 million barrels per day in 1990 while the former Soviet Union produced over 11 million barrels per day of total liquids during the same year.

African non-OPEC production is, at best, expected to increase slightly. Declines in Egyptian production should partially offset small gains from Angola and Tunisia.

North American production is expected to continue its decline. Canada should increase production slightly because of increased oil from tar sands and bitumen, as well as from natural gas liquids and condensates. However, these small increases will not offset the continued decline expected in the United States. This decline was briefly interrupted during the latter part of 1990 in response to events in the Middle East, with a rise in Alaskan production playing an important role. However, the decline in Alaskan production is expected to resume as the fields age. Most new incremental supplies, such as the Point McIntyre field discovered in 1989, are not expected from northern Alaska before the end of the decade.

In addition, U.S. production will decline because companies have been shifting investment away from drilling in the United States to foreign areas. For the first time, the major American oil companies have been spending more in foreign countries than in the United States. One major reason for this is that the United States has been well explored and the chances of finding another large field outside of a few environmentally sensitive areas are not as great as overseas. In addition, environmental restrictions that affect leasing of U.S. offshore areas and in Alaska are expected to reduce potential production. Finally, the cost of production in the United States is higher than elsewhere because of the size and age of its fields. These negative factors are expected to result in production declines that more than offset increased offshore production projected in the Pacific and from recent large deepwater discoveries in the Gulf of Mexico.

## Trends in Refining Capacity

Increased investments in refining operations are expected during the next two decades because of an expanding world economy, an increasing demand for lighter petroleum products, and a growing concern over environmental issues. To meet currently projected levels of oil demand, distillation and downstream capacity

will have to be added at rates comparable to or greater than the rates experienced in the last 5 years.

Following the Iranian revolution in 1979 and subsequent crude oil price increases, world oil consumption fell. As this trend continued through the early 1980's, world oil refining capacity also declined. The collapse of oil prices in 1986 led to an increase in petroleum consumption and a rebound in refining capacity. Since then, foreign refining capacity has been growing at an average annual rate of almost 0.7 percent, reaching 59.1 million barrels per day in 1991. By comparison, U.S. refining capacity has remained fairly steady since 1985 after losing a half million barrels per day of distillation capacity in 1984 and 1985. In 1991, U.S. refining capacity was 15.7 million barrels per day, or 20.9 percent of total world refining capacity.

World consumption of light products (mainly liquefied petroleum gas, gasoline, distillate and jet fuel) has increased from 32.9 million barrels per day in 1975 to 53.0 million barrels per day in 1989. Foreign consumption of light products as a percent of total petroleum consumption has increased from 68.6 percent in 1975 to 76.5 percent in 1989. The share of light products consumed in the United States continues to be greater than foreign shares, reaching 92.1 percent of total U.S. petroleum consumption in 1989. To meet the higher demand for light products, foreign refiners have installed 4.3 percent more thermal cracking and 4.4 percent more catalytic cracking capacity annually since 1986. By continuing to increase thermal cracking capacity at similar annual growth rates and nearly doubling the annual growth rate of catalytic cracking capacity, foreign refineries can, in 20 years, achieve the technical sophistication of current U.S. refineries. Assuming that utilization rates could be as high as 90 percent, foreign distillation capacity would have to increase at a rate of about 1 percent annually over the next 20 years to meet the expected increase in demand. Some of this refining capacity could be added in the Caribbean where, in the last several years, a number of refineries have been reactivated. In addition, new refineries are likely to be constructed in the Middle East and Far East for export purposes and in developing nations to satisfy increasing domestic demand.

## Comparison of International Oil Projections

Projections of world oil markets invariably involve considerable uncertainty. This uncertainty is generated by political events such as the recent Persian Gulf war

or the demise of communism and command economies in Eastern Europe and the former Soviet Union. Uncertainty also arises from the difficulty of knowing key determinants of supply and demand such as future world oil prices, economic growth rates, exchange rates, changes in efficiency and conservation, and environmental factors.

The variation between the *International Energy Outlook 1992 (IEO92)* and several other projections reflects this uncertainty (Table 7). The areas of greatest disagreement include production/consumption in the former Soviet Union/China, world oil prices, and demand growth in the developing countries. Conversely, estimates of future non-OPEC production outside of the CPE's vary by not much more than 10 percent, while OECD consumption estimates show little growth and vary to an even smaller degree.

Uncertainty over the CPE's represents the greatest uncertainty in world energy markets. The rapid political and economic changes occurring in these countries make projections for these countries difficult, with correspondingly wide uncertainty ranges for consumption (Table 3) and oil production capacity (Table 4). This *IEO92* is more pessimistic than previous ones for production/consumption in the next 5 to 10 years, and more optimistic for the following decade.

*IEO92* has higher levels of demand from the developing countries and higher levels of non-OPEC production than previous *IEO's*. Oil consumption is expected to grow faster in the developing countries because economic growth rates are projected to be higher than previously expected and because of the increased supply of oil that is projected to be available at the projected price levels to meet this higher demand. Previous projections showed prices increasing from *IEO92* levels because of increasing demand in the developing countries, without the availability of additional supplies.

Total non-OPEC production is now expected to increase steadily until the end of the decade, when it should plateau and begin a slow decline. Declines in the United States are expected to be offset by increases elsewhere. This *IEO92* is more optimistic than previous ones, and also more optimistic than other projections such as those in Table 7. Non-OPEC production has historically been underpredicted, with more oil being found when declines were projected. *IEO92* revises past projections in large part because of record production levels expected in the North Sea. Increased non-OPEC production is also expected from the Middle East (Syria and Yemen), the Far East (Australia, India, Malaysia, Papua New-Guinea), and Latin America (Mexico, Brazil, Colombia).

**Table 1. World Oil Prices, 1979-2010**  
(1990 Dollars per Barrel)

Year	Price Cases		
	Low	Base	High
1979		\$36.23	
1980		51.96	
1981		51.79	
1982		44.08	
1983		37.06	
1984		35.24	
1985		31.98	
1986		16.17	
1987		20.29	
1988		15.77	
1989		18.81	
1990		21.78	
1991	\$17.90	18.40	\$19.10
1992	16.10	18.70	21.50
1993	15.20	18.90	22.30
1994	15.60	19.80	23.80
1995	16.00	20.80	25.30
1996	16.30	21.80	26.80
1997	16.70	22.90	28.20
1998	17.10	24.00	29.60
1999	17.50	25.20	30.80
2000	17.90	26.40	31.80
2001	18.30	27.40	32.90
2002	18.80	28.30	34.00
2003	19.20	29.10	35.00
2004	19.70	29.80	36.00
2005	20.10	30.50	36.90
2006	20.60	31.10	37.70
2007	21.10	31.70	38.50
2008	21.60	32.30	39.20
2009	22.10	32.90	39.80
2010	22.60	33.40	40.20

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

Source: **History:** Energy Information Administration, *Monthly Energy Review*, DOE/EIA-0035(91/12) (1991). **Projections:** Energy Information Administration, *Oil Market Simulation Model User's Manual* DOE/EIA-MO28(92) (1992).

**Table 2. World Oil Consumption and Production: Base Case**  
(Million Barrels per Day)

Supply and Disposition	History			Projections		
	1988	1989	1990	1995	2000	2010
<b>Market Economies</b>						
<b>Production</b>						
United States <sup>a</sup> .....	10.47	9.88	9.68	9.1	8.5	8.3
Canada .....	2.04	2.03	2.02	2.1	2.2	2.3
OECD Europe .....	4.48	4.41	4.57	6.2	6.2	4.4
OPEC .....	21.85	23.73	25.11	27.1	30.9	41.9
Other Countries <sup>b</sup> .....	10.06	10.39	10.76	13.1	13.7	11.5
Net CPE Exports .....	2.17	1.87	1.65	0.7	0.3	0.0
<b>Total</b> .....	<b>51.08</b>	<b>52.31</b>	<b>53.79</b>	<b>58.2</b>	<b>61.8</b>	<b>68.4</b>
<b>Consumption</b>						
United States <sup>a</sup> .....	17.28	17.33	16.99	17.8	18.4	20.1
U.S. Territories .....	0.19	0.21	0.20	0.2	0.2	0.3
Canada .....	1.69	1.73	1.70	1.8	1.9	1.9
Japan .....	4.75	4.98	5.22	5.9	6.3	6.3
Australia and New Zealand .....	0.75	0.79	0.83	0.9	0.9	1.0
OECD Europe .....	12.43	12.53	12.59	13.7	13.8	14.0
Other Market Economies .....	13.90	14.68	15.44	18.1	20.5	25.1
<b>Total</b> .....	<b>50.99</b>	<b>52.25</b>	<b>52.97</b>	<b>58.5</b>	<b>62.1</b>	<b>68.7</b>
Discrepancy <sup>c</sup> .....	-0.09	-0.06	-0.82	0.3	0.3	0.3
<b>Centrally Planned Economies<sup>d</sup></b>						
<b>Production</b>						
China .....	2.73	2.76	2.77	2.9	3.1	3.7
Former Soviet Union .....	12.50	12.14	11.40	8.5	9.5	11.0
Other .....	0.44	0.43	0.40	0.5	0.6	0.9
<b>Total</b> .....	<b>15.67</b>	<b>15.33</b>	<b>14.57</b>	<b>11.8</b>	<b>13.2</b>	<b>15.6</b>
<b>Consumption</b>						
China .....	2.15	2.32	2.28	2.7	3.1	3.7
Former Soviet Union .....	8.89	8.74	8.40	6.5	7.5	8.9
Other .....	2.47	2.40	1.96	2.0	2.3	3.0
<b>Total</b> .....	<b>13.51</b>	<b>13.46</b>	<b>12.64</b>	<b>11.1</b>	<b>12.9</b>	<b>15.6</b>
<b>World Oil Consumption</b> .....	<b>64.50</b>	<b>65.71</b>	<b>65.90</b>	<b>69.6</b>	<b>75.0</b>	<b>84.3</b>

<sup>a</sup>Includes the 50 States and the District of Columbia.

<sup>b</sup>Includes Australia, New Zealand, and the U.S. Territories.

<sup>c</sup>Includes net stock withdrawals.

<sup>d</sup>Includes former, evolving, and current Centrally Planned Economies.

OECD = Organization for Economic Cooperation and Development.

OPEC = Organization of Petroleum Exporting Countries.

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 1990*, DOE/EIA-0219(90) (1992); **Projections:** Energy Information Administration, *Oil Market Simulation Model User's Manual* DOE/EIA-MO28(92) (1992) and *Annual Energy Outlook 1992* DOE/EIA-0383(92) (1992).

**Table 3. World Oil Consumption**  
(Million Barrels per Day)

Region/Country	Projection Ranges										
	History		1995			2000			2010		
	1989	1990	Base	Low	High	Base	Low	High	Base	Low	High
<b>Market Economies</b>											
<b>OECD</b>											
United States <sup>a</sup>	17.3	17.0	17.8	17.5	18.3	18.4	17.9	19.5	20.1	19.3	22.4
Canada	1.7	1.7	1.8	1.6	2.0	1.9	1.4	2.2	1.9	1.3	2.4
Japan	5.0	5.2	5.9	5.2	6.4	6.3	5.1	7.1	6.3	4.7	7.7
Europe	12.5	12.9	13.7	12.9	14.3	13.8	12.5	14.9	14.0	12.2	15.7
United Kingdom	1.7	1.7	1.9	1.7	2.1	1.9	1.5	2.3	1.9	1.5	2.6
France	1.9	1.8	2.0	1.8	2.2	2.1	1.6	2.3	2.1	1.5	2.5
Germany <sup>b</sup>	2.3	2.7	2.5	2.2	2.8	2.5	2.0	3.0	2.5	1.9	3.4
Italy	1.9	1.8	2.1	1.9	2.3	2.1	1.8	2.4	2.2	1.7	2.7
Netherlands	0.7	0.7	0.8	0.7	0.9	0.8	0.7	0.9	0.8	0.6	1.0
Other Europe	4.0	4.1	4.4	3.8	4.8	4.4	3.4	5.2	4.5	3.1	5.6
Other OECD	0.9	1.0	1.1	1.0	1.3	1.2	0.9	1.5	1.3	0.9	1.7
<b>Total</b>	<b>37.6</b>	<b>37.8</b>	<b>40.3</b>	<b>39.2</b>	<b>41.2</b>	<b>41.6</b>	<b>39.7</b>	<b>43.4</b>	<b>43.6</b>	<b>41.0</b>	<b>46.8</b>
OPEC	4.1	4.4	4.9	4.7	5.3	5.5	4.8	6.3	7.0	5.9	8.3
Other Developing Countries	10.5	11.1	13.2	12.0	14.3	15.0	12.5	17.1	18.1	14.3	21.6
<b>Total Market Economies</b>	<b>52.2</b>	<b>53.3</b>	<b>58.5</b>	<b>56.8</b>	<b>60.0</b>	<b>62.1</b>	<b>58.9</b>	<b>65.0</b>	<b>68.7</b>	<b>64.0</b>	<b>73.7</b>
<b>Centrally Planned Economies<sup>c</sup></b>											
China	2.3	2.3	2.7	2.5	2.9	3.1	2.7	3.5	3.7	3.0	4.4
Former Soviet Union	8.7	8.4	6.5	5.0	8.0	7.5	6.0	9.0	8.9	6.3	11.4
Other CPE	2.4	2.0	2.0	1.7	2.1	2.3	2.0	2.5	3.0	2.4	3.6
<b>Total</b>	<b>13.5</b>	<b>12.6</b>	<b>11.1</b>	<b>9.6</b>	<b>12.6</b>	<b>12.9</b>	<b>11.3</b>	<b>14.5</b>	<b>15.6</b>	<b>12.8</b>	<b>18.3</b>
<b>World Total</b>	<b>65.7</b>	<b>65.9</b>	<b>69.6</b>	<b>67.3</b>	<b>71.7</b>	<b>75.0</b>	<b>71.4</b>	<b>78.3</b>	<b>84.3</b>	<b>78.8</b>	<b>89.9</b>

<sup>a</sup>Includes the 50 States and the District of Columbia. U.S. Territories are included in "Other OECD."

<sup>b</sup>The 1989 amount is for West Germany.

<sup>c</sup>Includes former, evolving, and current Centrally Planned Economies.

OECD = Organization for Economic Cooperation and Development.

OPEC = Organization of Petroleum Exporting Countries.

Notes: High and low range values for Europe and the 4 regional totals are not equal to the sum of the component countries or country groups but consist of the base value adjusted by the quantity: the square root of the sum of the squared deviations of the respective component countries or country groups from their base value. Other totals may not equal sum of components because of independent rounding.

Sources: **History:** Energy Information Administration, *International Energy Annual 1990*, DOE/EIA-0219(90) (1992) and *Monthly Energy Review*, DOE/EIA-0035(91/12) (1991). **Projections:** Energy Information Administration, *Annual Energy Outlook 1992*, DOE/EIA-0383(92) (1992); *Oil Market Simulation Model User's Manual* DOE/EIA-MO28(92) (1992); and World Energy Projection System Spreadsheet, 1992.

**Table 4. World Oil Production Capacity Assumptions**  
(Million Barrels per Day)

Region/Country	Assumptions								
	History		Estimated	1995		2000		2010	
	1989	1990	1991	Low	High	Low	High	Low	High
<b>Market Economies</b>									
<b>Non-OPEC</b>									
United States <sup>a</sup>	10.1	9.7	9.8	8.5	9.8	7.5	9.4	7.0	9.0
Canada	2.0	2.0	2.1	2.0	2.3	2.0	2.5	2.0	2.6
Mexico	3.0	3.0	3.2	3.4	3.9	3.4	4.3	3.9	4.3
North Sea	4.0	4.2	4.3	5.1	5.8	4.9	6.1	3.3	4.1
Other Non-OPEC	8.3	8.4	8.6	9.5	10.9	9.4	11.8	7.3	9.2
<b>Total</b>	<b>27.4</b>	<b>27.3</b>	<b>28.0</b>	<b>29.7</b>	<b>31.7</b>	<b>29.1</b>	<b>32.6</b>	<b>25.2</b>	<b>28.3</b>
<b>OPEC</b>									
Algeria	1.3	1.4	1.4	1.2	1.3	1.2	1.5	1.3	2.0
Ecuador	0.3	0.3	0.3	0.3	0.3	0.2	0.3	0.1	0.1
Gabon	0.2	0.3	0.3	0.3	0.4	0.2	0.2	0.1	0.1
Indonesia	1.5	1.5	1.7	1.3	1.5	1.3	1.7	0.7	0.9
Iran	3.0	3.2	3.4	3.0	3.4	3.2	4.1	3.9	5.6
Iraq <sup>b</sup>	2.9	2.2	0.3	2.9	3.3	3.5	4.6	5.1	7.6
Kuwait <sup>b,c</sup>	2.8	1.7	0.2	2.1	2.4	2.6	3.0	2.9	4.0
Libya	1.7	1.6	1.6	1.6	1.7	1.5	1.8	1.7	2.4
Nigeria	1.8	1.8	2.0	1.9	2.0	2.0	2.3	1.9	2.6
Qatar	0.5	0.5	0.5	0.4	0.6	0.5	0.5	0.6	0.7
Saudi Arabia <sup>c</sup>	8.8	8.5	9.1	8.8	10.3	9.6	12.5	11.7	17.4
United Arab Emirates	2.1	2.5	2.7	2.4	2.8	2.6	3.4	3.6	5.3
Venezuela	2.6	2.6	2.6	2.5	2.9	3.0	3.9	4.2	6.2
Persian Gulf	20.1	18.6	16.2	20.5	22.0	23.1	26.5	30.4	37.3
<b>Total</b>	<b>29.5</b>	<b>28.1</b>	<b>26.0</b>	<b>29.9</b>	<b>31.5</b>	<b>33.3</b>	<b>36.9</b>	<b>42.2</b>	<b>49.4</b>
<b>Net CPE<sup>d</sup> Exports</b>	<b>1.8</b>	<b>1.9</b>	<b>1.3</b>	<b>-0.4</b>	<b>1.8</b>	<b>-0.9</b>	<b>1.5</b>	<b>-1.8</b>	<b>1.9</b>
<b>Total Market Economies</b>	<b>58.7</b>	<b>57.2</b>	<b>54.0</b>	<b>60.7</b>	<b>63.5</b>	<b>63.6</b>	<b>68.7</b>	<b>67.9</b>	<b>76.0</b>
<b>Centrally Planned Economies<sup>d</sup></b>									
China	2.7	2.8	2.8	2.8	3.0	2.8	3.4	3.2	4.2
Former Soviet Union	12.0	11.4	10.4	7.0	10.0	8.0	11.0	9.0	13.0
Other	0.4	0.4	0.3	0.3	0.5	0.5	0.7	0.9	1.1
<b>Total</b>	<b>15.1</b>	<b>14.6</b>	<b>13.5</b>	<b>10.3</b>	<b>13.3</b>	<b>11.6</b>	<b>14.7</b>	<b>13.5</b>	<b>17.7</b>
<b>World Total</b>	<b>72.0</b>	<b>70.0</b>	<b>67.5</b>	<b>71.6</b>	<b>75.0</b>	<b>76.4</b>	<b>81.9</b>	<b>83.8</b>	<b>92.5</b>

<sup>a</sup>Includes the 50 States and the District of Columbia.

<sup>b</sup>1990 estimate is pre-Iraqi invasion capacity.

<sup>c</sup>Includes 50 percent of Neutral Zone capacity.

<sup>d</sup>Includes former, evolving, and current 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. 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, World Energy Projection System Spreadsheet, 1992.

**Table 5. Annual Growth Rates of Real Gross Domestic Product (GDP): Base Case**  
(Percent)

Country/Region	Average Annual GDP Growth Rates				
	History			Assumptions	
	1970-1980	1980-1985	1985-1990	1990-2000	2000-2010
<b>World</b> .....	3.6	2.4	2.9	2.8	3.0
<b>Market Economies</b> .....	3.6	2.3	3.4	3.1	3.0
<b>Total OECD</b> .....	3.1	2.5	3.4	2.7	2.6
United States <sup>a</sup> .....	2.7	2.7	2.9	2.3	2.1
Canada .....	4.6	2.9	3.0	2.5	2.7
Japan .....	4.5	3.7	4.6	4.1	3.8
OECD Europe .....	3.0	1.5	3.5	2.6	2.5
<b>Developing Countries</b> .....	5.5	1.6	3.4	4.5	4.2
OPEC .....	5.9	-1.5	2.1	4.1	4.2
Other .....	5.3	3.2	4.0	4.7	4.2
<b>Centrally Planned Economies<sup>b</sup></b> ..	3.9	2.7	0.5	0.9	3.2
Former Soviet Union .....	3.2	2.2	1.7	-1.1	1.7
China .....	NA	10.1	7.8	7.2	5.0

<sup>a</sup>Projected growth rates are of real gross national product (GNP) as presented in the *Annual Energy Outlook 1992*.

<sup>b</sup>Includes former, evolving, and current Centrally Planned Economies.

OECD = Organization for Economic Cooperation and Development.

OPEC = Organization of Petroleum Exporting Countries.

NA = Not available.

Note: Projected growth rates are calculated from aggregate real gross domestic product in 1985 dollars at 1985 exchange rates.

Sources: **History:** Wharton Econometric Forecasting Associates, World Economic Service and *World Economic Service Historical Data*, April 1991 (1991). **Projections:** Energy Information Administration, *Annual Energy Outlook 1992*, DOE/EIA-0383(92) (1992); derived from Wharton Econometric Forecasting Associates, World Economic Service, and *World Economic Outlook* (January and October 1991).

**Table 6. World Crude Oil Reserves**  
(Billion Barrels)

Region/Selected Countries	Crude Oil Reserves <sup>a</sup>	
	<i>Oil and Gas Journal</i> (1/1/92)	<i>World Oil</i> (1/1/91)
<b>North America</b> .....	83.1	84.0
Canada .....	5.6	6.4
Mexico .....	51.3	51.3
United States <sup>b</sup> .....	26.3	26.3
<b>Central and South America</b> .....	68.4	69.9
Ecuador .....	1.6	1.4
Venezuela .....	59.1	60.1
<b>Western Europe</b> .....	14.5	23.4
United Kingdom .....	4.0	4.0
Other North Sea .....	9.0	17.8
Other Western Europe .....	1.6	1.7
<b>Eastern Europe and Former Soviet Union</b> .....	58.5	64.8
Former Soviet Union <sup>c</sup> .....	57.0	63.2
<b>Middle East</b> .....	661.5	602.5
Iran .....	92.9	63.0
Iraq .....	100.0	100.0
Kuwait <sup>d</sup> .....	96.5	98.0
Qatar .....	3.7	3.7
Saudi Arabia <sup>d</sup> .....	260.3	260.3
United Arab Emirates .....	98.1	66.5
<b>Africa</b> .....	60.5	62.1
Algeria .....	9.2	9.5
Egypt .....	4.5	6.2
Gabon .....	0.7	0.9
Libya .....	22.8	22.9
Nigeria .....	17.9	17.4
Other Africa .....	5.4	5.2
<b>Far East/Oceania</b> .....	44.1	54.7
Australia/New Zealand .....	1.7	3.0
China .....	24.0	30.8
Indonesia .....	6.6	10.7
<b>Total OPEC</b> .....	769.4	714.5
<b>World Total</b> .....	991.0	961.4

<sup>a</sup>Reserves include proved reserves and indicated additional reserves. Some foreign countries have a less restrictive definition than EIA of proved reserves that are reported to and published by the various trade journals.

<sup>b</sup>The U.S. data are as of 12/31/90.

<sup>c</sup>East Germany is included in Western Europe for the 1/1/92 data and in Eastern Europe for the 1/1/91 data.

<sup>d</sup>Includes 50 percent of the Neutral Zone.

OPEC = Organization of Petroleum Exporting Countries.

Sources: *Oil and Gas Journal*, 89, 52 (December 30, 1991); *World Oil*, 212, 8 (August 1991); and Energy Information Administration, *U.S. Crude Oil Natural Gas and Natural Gas Liquids Reserves*, DOE/EIA-0216(90), 1991.



**Table 7. Comparison of World Oil Projections**  
(Million Barrels per Day)

Projections	Oil Consumption				Oil Production				World Oil Price <sup>a</sup>
	World	OECD	Former Soviet Union/China	Other	World	OPEC	Former Soviet Union/China	Other	
<b>Year 2000</b>									
IEO92 .....	75.0	41.6	10.6	22.8	74.7	30.9	12.6	31.2	\$26.40
IEO91 .....	73.2	41.9	10.9	20.4	72.8	32.3	13.0	27.5	26.40
Canada <sup>b</sup> .....	72.8	41.9	10.0	20.9	72.8	33.4	13.3	26.1	23.20
DRI .....	72.9	40.9	10.8	21.2	73.2	33.4	13.2	26.6	27.20
County NatWest <sup>c</sup> .....	75.4	42.3	10.6	22.5	75.7	32.9	12.8	30.0	20.00
World Bank .....	72.6	37.8	12.5	22.3	72.6	31.0	14.7	26.9	22.90
<b>Year 2010</b>									
IEO92 .....	84.3	43.6	12.6	28.1	84.0	41.9	14.7	27.4	\$33.40
IEO91 .....	78.7	43.8	13.0	21.9	78.3	39.8	13.9	24.6	33.40
Canada .....	78.5	44.4	9.1	25.0	78.4	42.7	10.7	25.0	27.00
DRI .....	80.6	43.6	11.4	25.6	80.8	40.6	13.3	26.9	35.70

<sup>a</sup>1990 dollars per barrel.

<sup>b</sup>Estimates from Canada include only net exports from the former Centrally Planned Economies, and not consumption/production estimates. For purposes of comparability, the consumption/production estimates underlying the net export projections (derived from the *International Energy Outlook 1989*) are added to the Canadian estimates.

<sup>c</sup>West Texas Intermediate oil price. The U.S. refiner acquisition cost of imported crude oil used as the world oil price for the *IEO92* and other projections listed here runs about \$2 to \$3 per barrel less than West Texas Intermediate.

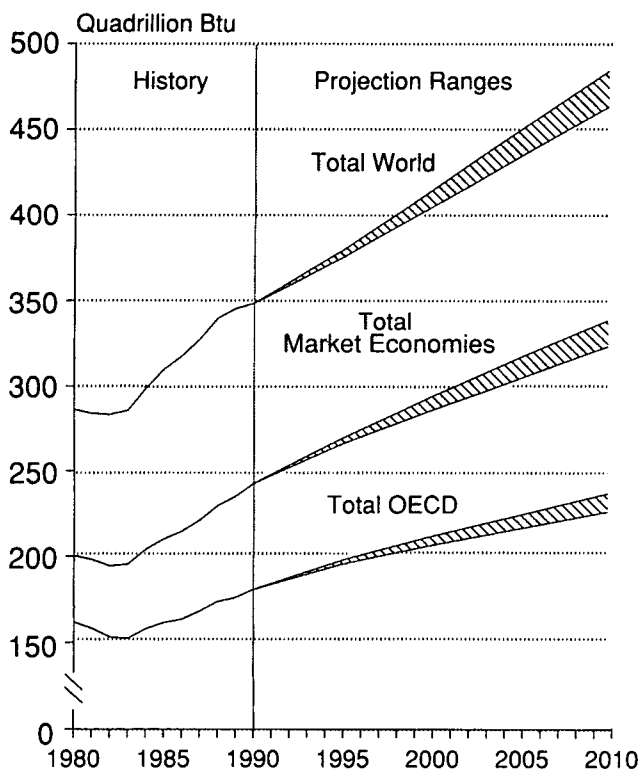
OECD = Organization for Economic Cooperation and Development.

Sources: IEO92—*International Energy Outlook 1992*, DOE/EIA-0484(92). IEO91—*International Energy Outlook 1991*, DOE/EIA-0484(91). Canada—*Canadian Energy Supply and Demand 1990 - 2010*, National Energy Board, June 1991. DRI—DRI/McGraw-Hill, *International Oil Bulletin*, Fall 1991. County NatWest—County NatWest USA, *Oil Market Outlook*, January 1992. World Bank—*Price Prospects for Major Primary Commodities*, Report No. 814/90, December 1990.

# World Energy Consumption

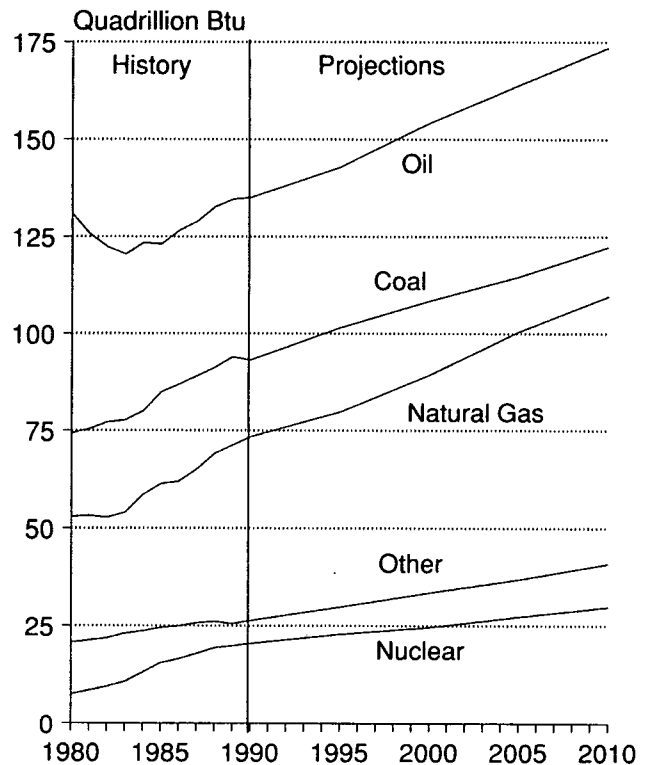
World consumption of total primary energy is projected to grow steadily from 1990 to the year 2010 (Figure 4), on average about half as fast as world economic growth as measured by gross domestic product (GDP) (Table 5). Oil is the most important source of energy (Figure 5), but the growth in oil consumption through 2010 is the slowest of all the major energy sources. The fastest growing fossil fuel is natural gas, which will grow over one and one-half times as fast as oil. Table 8 lists consumption by major energy source. World energy consumption by region is presented in Table 9. Energy consumption in the developing countries will grow about twice as fast as that in the industrial countries that make up the Organization for Economic Cooperation and Development (OECD).

**Figure 4. World Energy Consumption by Region, 1980-2010**



Sources: **History:** Energy Information Administration, *International Energy Annual 1990*, DOE/EIA-0219(90). **Projections:** Table 9.

**Figure 5. World Energy Consumption by Type, 1980-2010**



Sources: **History:** Energy Information Administration, *International Energy Annual 1990*, DOE/EIA-0219(90). **Projections:** Table 8.

In absolute terms, the United States, the former Soviet Union, and China consumed the most energy in 1990 and will remain the largest consumers through 2010. Total energy consumption in OECD Europe was about equal to that of the former Soviet Union in 1989; but, while energy consumption continued to grow in OECD Europe in 1990, it actually declined in the former Soviet Union. Indeed, total energy consumption in the former Soviet Union is likely to be lower in 1995 than it was in 1990 (Table 9).

Among the OECD countries, Japan consumes the most energy next to the United States. However, the United States currently produces over 80 percent of the energy it consumes, though greater reliance on imports of oil

could reduce this level of self-sufficiency below 80 percent by 2010. In contrast, Japan must import much of the energy it consumes because of the virtual absence of indigenous energy resources. Economic growth in Japan is projected to be the fastest among the OECD countries, growing an average of about 4 percent per year between 1990 and 2010. To support this growth, Japan is expected to expand both nuclear production and natural gas imports substantially. OECD Europe, though not expected to grow as fast as Japan, will also increase natural gas imports substantially, both from the Middle East and from the former Soviet Union.

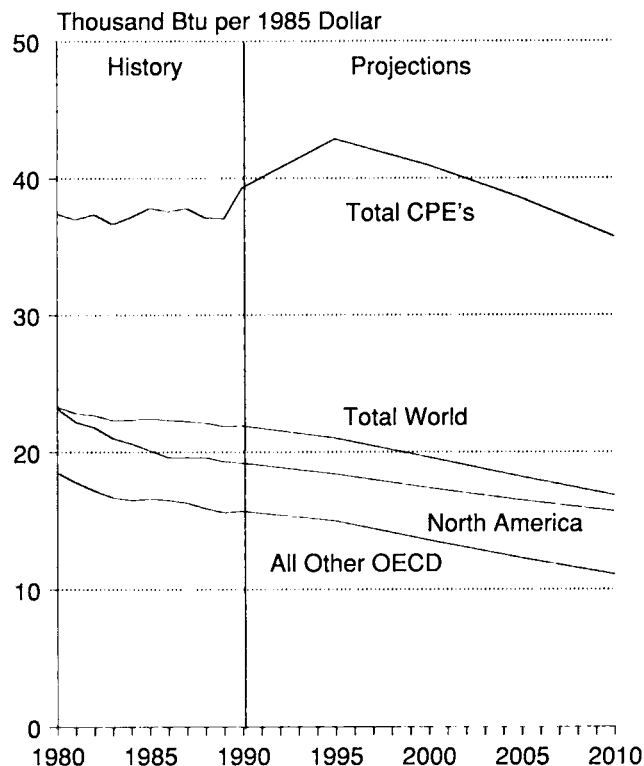
Economic activity in the developing countries, excluding the former, evolving, and current CPE's, henceforth called simply the CPE's, grows at an average rate of 4.4 percent per year between 1990 and 2010, resulting in the fastest rate of growth in energy consumption as well. The newly industrialized countries, particularly along the Pacific Rim, should experience exceptionally strong economic growth over this period. The growth of urban areas and industrial activities that accompany development bring with them increased demands for transportation, electrification, and all the other energy-using appliances and amenities associated with modern-day living.

### Energy Intensity

The turmoil of the political and economic changes occurring in the CPE's impacts very strongly on the energy intensity of economic activity in those countries, particularly between now and 1995 (Figure 6). Defined as the ratio of total energy consumption to gross domestic product (GDP), the energy intensity of economic activity actually rises in the CPE's between 1990 and 1995, while it continues to decline in the rest of the world. Energy consumption in the CPE's grows less than 1 percent per year on average between 1990 and 1995, but GDP declines about 1 percent per year over this period because of the transition from command to market economies. At present, the CPE's are by far the world's most inefficient users of energy. However, this measure of efficiency is based on current estimates of GDP, which are highly questionable. No doubt considerable progress can be made at reducing inefficiency in these countries, particularly if efforts at general economic reform succeed.

The energy intensity of economic activity is greater in OECD North America (the United States and Canada) than in the rest of the OECD countries considered together. A major contributor to this difference is the importance of hydroelectric power in Canada and the

**Figure 6. Energy Consumption per GDP Ratio, 1980-2010**



Note: CPE's include former, evolving, and current Centrally Planned Economies.

Sources: **History:** Wharton Econometric Forecasting Associates, *World Economic Service Historical Data 1991*; and Energy Information Administration, *International Energy Annual 1990*, DOE/EIA-219(90). **Projections:** Derived from Tables 5 and 9.

way in which the measurement of this source of power is converted from kilowatthours to the standard British thermal unit (Btu). In this report, the fossil-fuel conversion factor is applied to hydroelectric power generation. This conversion assumes that 1 Btu of electricity consumed requires about 3 Btu of energy inputs to produce. In the past, the International Energy Agency (IEA) in Paris used this convention as well, but the IEA changed its conversion methodology in 1991. Now, the IEA assumes 100 percent conversion efficiency for hydroelectric power. That is, 1 Btu of electricity consumed requires only 1 Btu of energy input to produce. If this new conversion methodology were applied in this report, the energy/GDP ratio for North America would drop substantially.

Future reductions in the energy intensity of economic activity worldwide must come from additional improvements in energy efficiency and energy

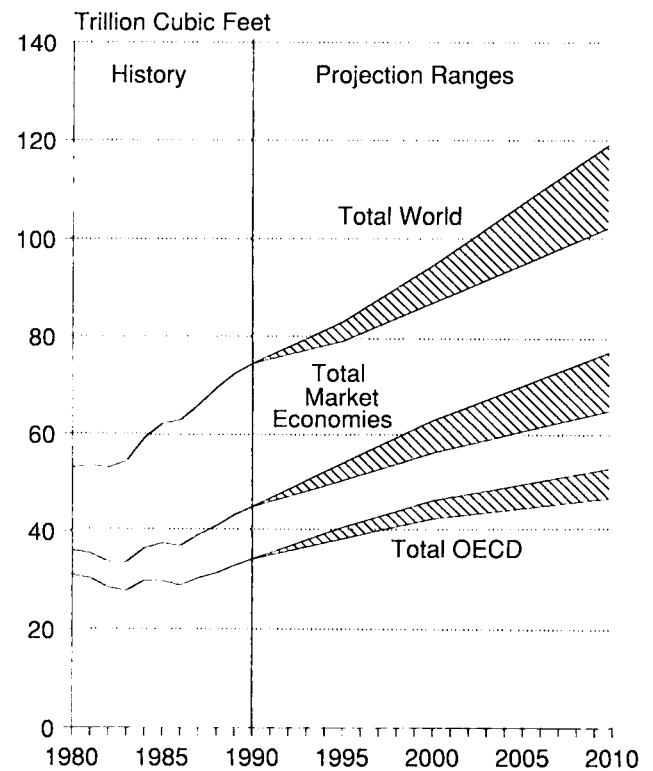
conservation. Technological innovation will also be an important ingredient in reducing overall energy intensity, as improvements become more difficult to implement. The changing mix of economic activity will act to reduce energy intensity, as structural changes alter the proportion of economic activity from energy-intensive heavy manufacturing and resource development to less energy-intensive services and high-technology industries.

Expansion of manufacturing in some newly industrialized countries and continued dependence on resource development in other developing countries will add to the overall energy intensity of economic activity in those regions. Growth in motor transportation and in electrification will add further to the general energy intensity of daily activity. Countries rich in energy resources, particularly certain OPEC nations, will increase the energy intensity of their economies as they use these resources to achieve economic goals. Petrochemical activities, in particular, require large inputs of oil and natural gas. Notwithstanding these developments, the general trend in the intensity of economic activity among the developing countries is down, as it is in the industrialized countries.

## Prospects for Natural Gas

Even with reductions in the intensity of economic activity anticipated between now and 2010, large amounts of additional energy will be required to achieve the rates of economic growth projected for this period (Table 5). Natural gas will provide an increasing share of total energy requirements, this share going from just over one-fifth of the total currently to just under one-fourth of all energy consumed by the year 2010. Natural gas could be the fastest growing energy source in the world over this period (Table 10 and Figure 7). Expectations for the role of natural gas in world energy markets have increased considerably in recent years. A major reason for this increase is that estimates of world natural gas resources also continue to rise. Recent technological advancements have added further to expectations for natural gas. With increased efficiency of gas-fired technology, electric utilities are more likely to consider natural gas as a competitive baseload fuel. The use of high-efficiency combined cycle systems is becoming more widespread not only in the utility sector but also in industry. In many countries, electric utilities have become cautious about investing in large baseload coal-fired and nuclear plants because of uncertainties concerning regulatory and environmental requirements. Natural gas-fired plants

**Figure 7. World Natural Gas Consumption, 1980-2010**



Sources: **History:** Energy Information Administration, *International Energy Annual 1990*, DOE/EIA-0219(90). **Projections:** Table 10.

are often preferred because smaller plants can be built faster and cheaper than can the larger plants, with no loss in performance in terms of energy efficiency or environmental impact.

Available worldwide, natural gas is particularly abundant in the former Soviet Union and the Middle East which, together, account for about two-thirds of the world's reserves. Natural gas has been the primary energy source in the former Soviet Union since 1986 and could account for almost half of all energy consumed in this region by the year 2010. Natural gas could be the major source of energy in several Western European countries by 2010 as well.

The distribution of natural gas reserves relative to areas of growing demand implies expanded trade in this important energy source. Major importers will be Japan and the countries of Eastern and Western Europe. Natural gas will serve to diversify energy imports in these regions and to reduce environmental problems associated with other fossil fuels, particularly coal.

Growth in natural gas consumption will be particularly dependent upon the availability of capital to develop new fields and to construct the required distribution systems.

A major incentive for increased use of natural gas is the growing concern over the environmental costs associated with energy use. Clean burning relative to other fossil fuels, natural gas use for electric power generation could come at the expense of both coal-fired and nuclear power plants, particularly in densely populated areas where environmental considerations are particularly important. Relatively low capital costs and improved technology, such as combined-cycle systems, will further encourage the use of natural gas for electric power generation. An additional market for natural gas will be for combined heat and power production in industry and for district heating in certain European countries. The ability to shift fuel use relatively quickly using dual-fired capabilities is particularly attractive to Europe, as it attempts to increase the diversity of energy supplies and the flexibility of energy markets. Increased use of natural gas will also result from its use as a transportation fuel in competition with gasoline and diesel fuel.

In the United States, the choice of natural gas for use by electric utilities will be the major factor contributing to increased consumption, but the absolute level of consumption is not expected to reach the 1972 historic high of 22.1 trillion cubic feet before the year 2000. Growth in gas use by electric utilities results from a substantial increase in combined-cycle generating capacity. However, new coal-fired steam units are expected as 2010 approaches, possibly resulting in reduced natural gas consumption. Natural gas consumption in the residential and commercial sectors will grow because of greater numbers of appliances but will also be constrained by efficiency improvements in equipment and buildings and increased use of electricity in the residential sector. Natural gas consumption in the industrial sector grows with increased use of natural gas in cogeneration, but peaks near the turn of the century. It declines somewhat thereafter, as industrial activity becomes less energy intensive and as certain industrial processes turn to electricity. New technologies that could affect consumption prospects considerably in the United States and elsewhere include the use of natural gas for space cooling and the use of compressed natural gas (CNG) in fleet motor vehicles.

Canadian pipeline exports to the United States are expected to grow through the late 1990's before leveling off somewhat at about 2 trillion cubic feet per year.

Natural gas trade between the United States and Mexico will be influenced by ongoing negotiations of a Free Trade Agreement. Mexico could begin exporting natural gas to the United States by 2000. Imports of liquefied natural gas (LNG) to the United States should grow substantially between now and 2010. Current constraints with respect to tanker capacity for transoceanic shipping and on liquefaction capacity should be eased during the 1990's.

International trade in natural gas and LNG continues to grow. Japan, for example, is and will continue to be totally dependent on imports. OECD Europe as a group imports considerable amounts, particularly from the former Soviet Union and Algeria. The former Soviet Union provided about one-third of all internationally traded natural gas in 1990. Within Europe itself, additional supplies are expected from Norway's Troll and Sheipner fields. Eastern Europe has also shown interest in importing Algerian and Norwegian gas in order to reduce its dependence on gas from the former Soviet Union.

Recent pipeline developments cited by the International Energy Agency (IEA) include linking Spain to the French grid to carry Norwegian gas, efforts by Portugal to develop a natural gas system, construction of the Midal/Stegal pipeline by Germany to carry gas from the former Soviet Union to Germany and other Western European countries, construction of a pipeline by Greece for Soviet gas, a planned pipeline between Ireland and the United Kingdom, a planned third pipeline from Norway to the European continent, and planned expansion of the Trans Mediterranean pipeline and consideration of a new pipeline through Morocco to Spain by Algeria. Also under consideration by the European Community are proposals to broaden access to existing gas transmission lines.

The consumption of natural gas grows most rapidly in the developing countries between 1990 and 2010, over 3 percent per year, compared to about 2 percent per year for the OECD countries taken as a group and about 1 percent per year for the United States. The Middle East countries in particular can exploit vast gas fields, collect associated gas from oil production, and substitute gas for oil for industrial production and electricity generation. The development of natural gas resources in developing countries outside of the Middle East will be highly dependent on foreign investments. However, certain countries may have difficulty obtaining the required capital because of existing debt, particularly in Latin America. Recent activities among the developing countries cited by the IEA include expanded use of natural gas by Egypt primarily for use

in new power plants, a contract for Qatar to supply LNG from its offshore North Dome field (the world's largest) to a Japanese electric utility company starting in 1997, and important investments in natural gas production and distribution facilities in Indonesia, Malaysia, Pakistan, and Thailand. These activities are aimed primarily at providing natural gas for electric power generation.

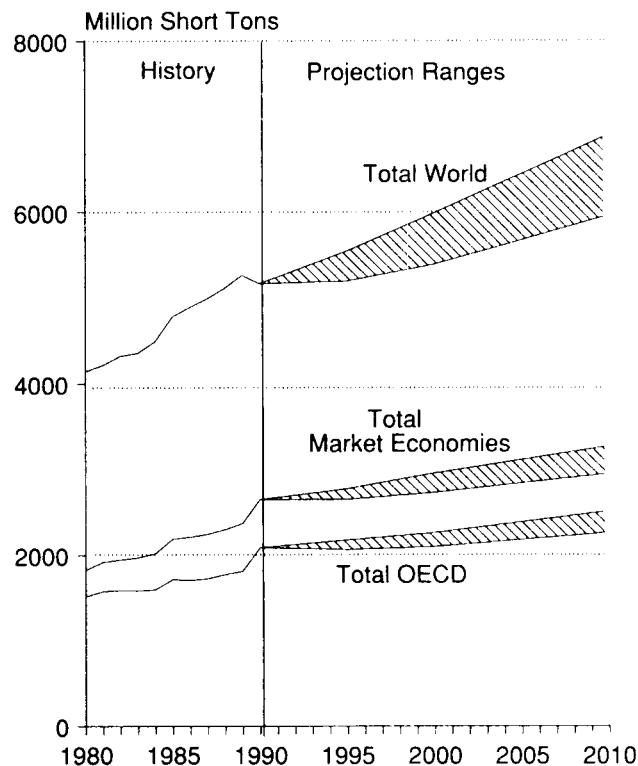
## Prospects for Coal

Consumption of coal is projected to grow in most parts of the world, but consumption could be lower in 2010 than it was in 1990 in Eastern and Western Europe and in the former Soviet Union (Table 11 and Figure 8). Next to oil, coal grows at the slowest rate among the major fuels and should lose a portion of its relative importance worldwide to natural gas. Coal will remain the most important energy source among the CPE's, except in the former Soviet Union where natural gas dominates. Coal could increase its relative importance in the CPE's taken together, primarily because of expected growth of coal consumption in China. Coal provides three-quarters or more of all energy consumed in China over the projection period.

In 1990, China, the United States, and the former Soviet Union accounted for about 56 percent of total coal production in the world. China was the leading producer at about 1.2 billion short tons, followed by the United States at about 1.0 billion short tons, and the former Soviet Union at about 0.7 billion short tons. Other major producers included Germany, Poland, India, Australia, and South Africa. China, the United States, India, and Australia are expected to expand coal production between now and 2010 to meet domestic needs. Major importing countries with limited coal reserves but growing needs from expanding economies include Japan, South Korea, Taiwan, Brazil, and several Western European countries. Another set of countries will experience growing demands coupled with declining supplies of domestic coal. These countries include the United Kingdom, Germany, Poland, the Czech and Slovak Federal Republic, and the European region of the former Soviet Union.

Given the distribution of world coal reserves compared with areas of growing demand, international coal trade should expand rapidly over the projection period (Figure 9). Currently, the United States and Australia account for about half of all internationally traded coal. Along with South Africa, these three countries could account for over two-thirds of total coal trade by 2000,

Figure 8. World Coal Consumption, 1980-2010



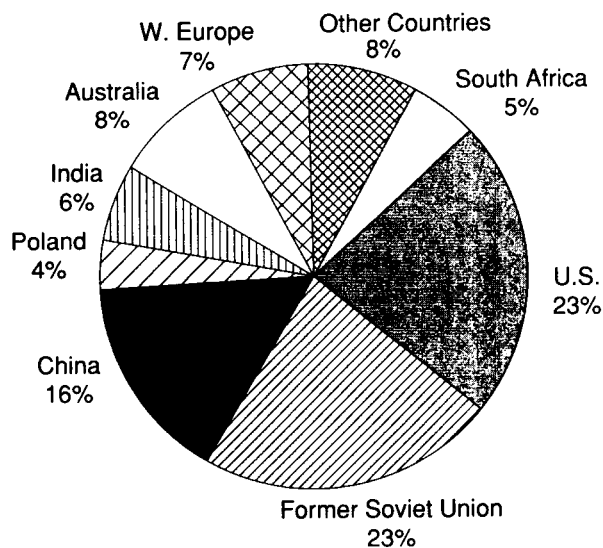
Sources: **History:** Energy Information Administration, *International Energy Annual 1990*, DOE/EIA-0129(90). **Projections:** Table 11.

increasing to three-quarters by 2010. Australia should remain the largest exporter of coal through 2005, but the United States could surpass Australia by the year 2010. In particular, the United States should increase its share of the European market because of freight costs and a comparative advantage for Australia to sell to Asia rather than to Europe.

Coal exports by the United States, 106 million short tons in 1990, could more than double by 2010. Coal exports will consist primarily of steam coal, more than 80 percent of total U.S. exports over this period. Exports of metallurgical coal decline through 2010. This pattern for U.S. trade reflects world coal demand patterns, with the electric power sector generating by far the greatest demand for coal through 2010. In contrast, the demand for metallurgical coal will reflect slower growth in demand for coking coal, as steel production slows and steel-making technologies improve.

The expected rise in coal exports by the United States and other coal exporters is largely a result of the decline in coal production in Europe, including Poland,

**Figure 9. World Coal Reserves**



Total = 1,167.3 Billion Short Tons

Source: Energy Information Administration, *International Energy Annual 1990*, DOE/EIA-0219(90).

as countries restructure their coal industries and eliminate non-competitive coal production. Similarly, production in Japan is to be phased out. The largest production cutbacks are expected in the United Kingdom, because of the privatization of the electric supply industry and the possible privatization of British Coal in the late 1990's, and in Germany, because of the elimination of production subsidies and the reduction of lignite production in Eastern Germany, a major pollutant. In Belgium, coal production should cease altogether in 1992.

At the same time, the demand for coal-generated electricity will continue to grow, particularly in Asia. Demand for seaborne steam coal should rise in Eastern Europe as well, as supplies from Poland and the former Soviet Union decline. Environmental concerns in Western Europe could also provide a market for U.S. premium coal, currently sold into metallurgical markets.

Environmental protection laws, such as the U.S. Clean Air Act Amendments of 1990, the development of clean

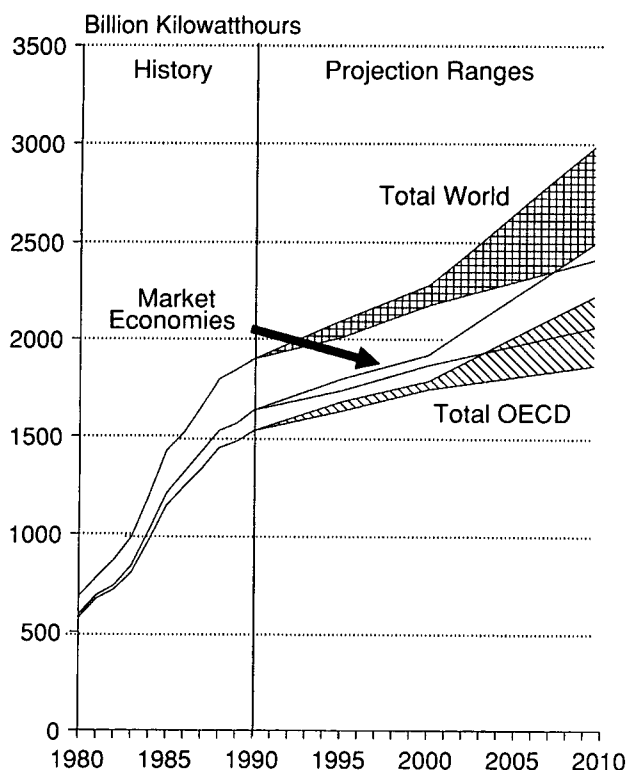
coal technologies and coal-based synthetic fuels, and developments in world coal trade will all have a major influence on prospects for coal in the United States and in the world. Concern over acid rain and possible climate change could stimulate various responses around the world, including greater efforts in the areas of clean coal-burning technology, conservation, or even enactment of taxes on the carbon content of fuels. Technologies to improve the efficiency of coal-fired electricity generation and to reduce coal-related emissions include pressurized fluidized bed combustion power plants and coal-gasification combined cycle plants. Growth in the production of synthetic fuels such as coal liquefaction will depend to a large degree on their competitiveness with conventional fuels, particularly oil. The world oil prices projected in this report suggest that commercial production of coal liquids will not be significant before 2010.

## Nuclear and Other Energy Sources

The consumption of nuclear power is not expected to grow as fast in the 1990's as it did in the 1980's, but consumption accelerates after 2000 (Table 12 and Figure 10). Lower rates of growth in the 1990's are attributable to reduced public acceptance, particularly since the 1986 Chernobyl disaster; relative costs, especially in the context of relatively low fossil fuel prices; and unique environmental problems, particularly the disposal of nuclear waste. Nuclear power which accounted for about 5.9 percent of total world energy consumption in 1990, will account for about 6.2 percent in 2010.

Without doubt the most significant development during the past year regarding nuclear power stemmed directly from the historic changes taking place in Eastern Europe and the former Soviet Union. The dramatic political and economic reforms occurring in these countries inevitably affected their energy economies, including nuclear power. Greater freedom of expression has allowed environmental considerations, which were suppressed in the past, to play a larger role in energy planning throughout these regions. Soviet anti-nuclear forces, for example, already have forced the abandonment of up to 100 gigawatts of planned nuclear capacity. Nuclear power programs in other Eastern European countries, such as the former East Germany, are currently in an uncertain state due primarily to heightened safety standards and public opposition. In general, political changes in the region during the past year have led to a reassessment of the current and future safety of Soviet-supplied nuclear reactors, and a desire to move towards western nuclear technology and safety standards.

**Figure 10. World Nuclear Energy Consumption, 1980-2010**



Sources: **History:** Energy Information Administration, *International Energy Annual 1990*, DOE/EIA-0219(90). **Projections:** Table 12.

At the start of 1991, there were 60 nuclear generating units operating in Eastern Europe (including the former Soviet Union): 5 in Bulgaria, 8 in the Czech and Slovak Federal Republic (CSFR), 4 in Hungary, and 43 in the former Soviet Union. A recent study of these reactors conducted by the United Nations International Atomic Energy Agency (IAEA) identified more than 1,000 specific problems that could lead to a nuclear disaster. Of prime concern is the threat of a Chernobyl-style accident at one of Eastern Europe's obsolete, Soviet-designed, WWER 440-230 pressurized water reactors. In particular, the IAEA report discovered severe problems with Bulgaria's Kozloduy nuclear complex, described by experts as "perhaps the most dangerous civilian nuclear power plants on earth." The CSFR's Bohunice power plant has also experienced several near-accidents recently, provoking concern in neighboring Austria.

Despite these dangers and concerns, there is great reluctance to shut down nuclear power plants in the countries of Eastern Europe and the former Soviet

Union. This reluctance is based primarily on two major factors: the need for independent, reliable power supplies and the lack of economically feasible alternatives (other than highly polluting coal). In the CSFR, for instance, nuclear power is a critical source of electricity to the country's energy-intensive, inefficient heavy industrial sector. In fact, the CSFR relies on nuclear power for nearly a third of its electric power. Bulgaria and Hungary are also heavily dependent on nuclear power, as are the newly independent, former Soviet republics of Lithuania and Ukraine. All fear that a shutdown of nuclear power plants could worsen electricity shortages and thus retard economic growth. Trying to satisfy all of these concerns will not be easy. One possible approach might be to postpone further nuclear development indefinitely while backfitting Soviet-designed nuclear plants with Western safety features. Such a solution, however, would be very expensive and possibly not acceptable to increasingly anti-nuclear public opinion in these countries.

The outlook for nuclear power in the rest of the world remains mixed. Some developments in other countries' nuclear programs include the following:

- The Dutch government has quietly lifted the moratorium on nuclear construction imposed in the aftermath of Chernobyl. Its aim is to increase the share of nuclear power from around 1 percent currently to 25 percent in the next century in order to reach the ambitious goals of cutting carbon dioxide emissions while reducing dependence on natural gas imports. At the same time, the country is investing in wind power generation capacity, which it hopes to increase from around 45 megawatts now to over 1,000 megawatts by the end of the century.
- Taiwan now has decided to proceed with construction of its long-delayed fourth nuclear power plant. This decision was taken for three main reasons: increasing electricity demand; limited potential for expansion of other electricity sources, particularly hydroelectric; and environmental constraints on fossil fuel use.
- Sweden has revised its timetable for phasing out nuclear power by 2010, acknowledging the great hardships the plan would have entailed. With nuclear power currently satisfying nearly 50 percent of total Swedish electricity demand, the government has decided that the realization of the desired non-nuclear Sweden will have to be postponed. Already, the 1995 target for beginning the phaseout has been scrapped.



- With nuclear power currently providing around 27 percent of Japan's electricity, and with plans to expand this to 45 percent by 2010, Japan remains one of the countries most firmly committed to nuclear power. There is concern, however, that this ambitious plan may be affected by the accident in February 1991 at the Mihama plant north of Kyoto, in which a generator tube burst and tons of radioactive water consequently gushed from one cooling system to another.
- The rapidly growing economies of the Asia Pacific Rim continue to constitute a potential area of growth for nuclear power. South Korea already has a substantial program of nuclear expansion in place, with the aim of making nuclear power the main electricity generator by 2000.

France is currently exporting approximately 40 billion net kilowatthours of nuclear-generated electricity to other European nations and may be exporting over 60 billion net kilowatthours of nuclear-generated electricity by 2010. Estimates of nuclear exports from France have been excluded from French nuclear consumption and have been included in the consumption figures for traditional French customers, including the United Kingdom, Germany, Italy, the Netherlands, and three countries (Belgium, Spain, and Switzerland) in the "Other Europe" region (Figure 10 and Table 12). Thus, the projections of nuclear consumption for these countries (in particular, Italy) do not necessarily reflect the trends in their domestic nuclear power programs.

Some of the same negatives facing the nuclear power industry at this time also confront the "renewables" sector (Table 13). 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. On the other hand, reliable supplies of affordable, and preferably indigenous, energy are of crucial importance to the developing countries. It is therefore likely that despite the problems associated with some renewable power sources, the developing countries will be forced to include them in their energy mix as a means of reducing energy dependence and of maintaining desired levels of economic growth.

The total installed worldwide hydroelectric generating capacity as of 1990 was 615 gigawatts-electric. Its share of world energy consumption, which was estimated at around 6.4 percent in 1990, is expected to exceed 8 percent by 2010. Among the countries with significant

amounts of hydroelectric power capacity are: the United States, 90.5 gigawatts-electric; former Soviet Union 64.4; Canada, 58.5; Brazil, 44.6; Japan, 37.3; China, 30.0; Norway, 26.5; and France, 22.9. Geothermal electricity generation constituted less than 1 percent of the world's total net electricity output in 1990.

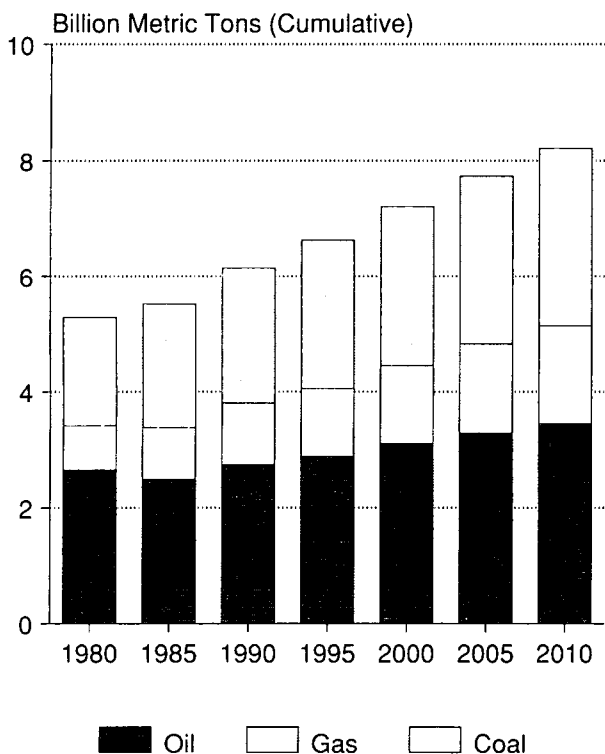
## Environmental Considerations

Many human activities, whether or not they are energy-related, have an impact on the environment. In terms of the energy sector, environmental impact ranges from a relatively localized impact, as in the case of a particular city's smog pattern, to the more regional or even global levels, as with acid rain and the "greenhouse effect." Of all the world's environmental problems, the greatest attention in recent years has been directed towards this latter phenomenon, also popularly referred to as "global warming." This attention centers primarily around the possibility that large-scale anthropogenic (man-made) emissions of "greenhouse gases" (primarily carbon dioxide, but also including methane, nitrous oxide, tropospheric ozone, and chlorofluorocarbons, or CFCs) could result in unacceptable levels of global warming in coming years.

Debate and controversy surrounding this issue has generally centered on (1) whether global warming is actually occurring, (2) if it is occurring, to what extent is man-made pollution, as opposed to natural forces (such as changes in cloud cover), contributing to it and, (3) what are the policy implications—can or should something be done about it? Although there is disagreement as to these three points, there is overall agreement regarding the trend towards increased atmospheric concentration of greenhouse gases, particularly carbon dioxide, by as much as 25 percent since the beginning of the industrial revolution. There is also a general consensus as to the two main causes of this increase: first, forest destruction, which both releases stored carbon into the atmosphere and at the same time reduces the absorption of CO<sub>2</sub> and its conversion by photosynthesis into oxygen; and second, the consumption of fossil fuels, which converts vast quantities of stored carbon from solid to gaseous form (mainly carbon dioxide) when the fuel is burned.

Total world carbon emissions from the burning of fossil fuels were approximately 6 billion tons in 1990, of which 45 percent were from the consumption of oil, 38 percent from coal, and 17 percent from the relatively "clean" fuel, natural gas (Figure 11). Assuming no change in current regulations, carbon emissions are

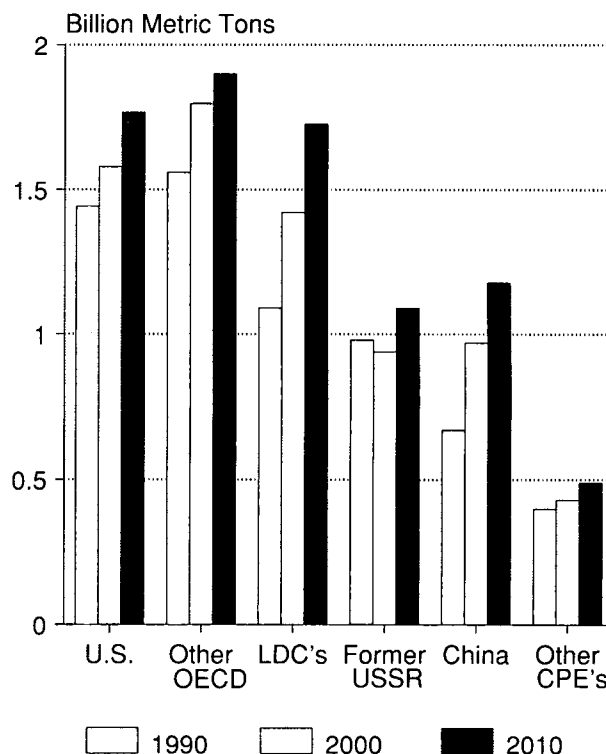
**Figure 11. World Carbon Emissions by Fuel Type, 1980-2010**



Sources: **History:** Derived from Energy Information Administration, *International Energy Annual 1990*, and *The Energy Journal*, Volume 4, No. 3. **Projections:** Derived from *The Energy Journal*, Volume 4, No. 3, and Table 8.

anticipated to grow to over 8 billion tons in 2010, with 42 percent from oil, 38 percent from coal, and 21 percent from natural gas. Most of this increase in carbon emissions is expected to come from the developing countries and the present and former Centrally Planned Economies (particularly China) (Figure 12). International efforts to reduce greenhouse gas emissions are in the early stages. The United Nations General Assembly has established an Intergovernmental Negotiating Committee for a Framework Convention on Climate Change, which hopes to have a formal treaty for an international agreement to control climate change ready for signature by June 1992, when the U.N. Conference on Environment and Development meets in Rio de Janeiro, Brazil. At the same time, the 12 heads of government of the European Community have pledged to stabilize carbon emissions at 1990 levels by the year 2000. In order to achieve this goal, an European Community

**Figure 12. Carbon Emissions by Region, 1980-2010**



Note: CPE's include former, evolving, and current Centrally Planned Economies.

Sources: **History:** Derived from *International Energy Annual 1990*, and *The Energy Journal*, Volume 4, No. 3. **Projections:** Derived from *The Energy Journal*, Volume 4, No. 3, and World Energy Projection Spreadsheet 1992.

carbon tax has been proposed, but not yet adopted in the face of numerous political and economic pressures against it.

Despite the continued concern over global warming, some of the world's attention has shifted in recent months to the immediately pressing environmental problems facing the current and former Centrally Planned Economies. In contrast to the global warming issue, the severity of these countries' environmental problems is not at all controversial, including, for example, problems resulting from heavy reliance on inexpensive coal resources as the basis for the development of heavy industry. The lack of adequate measures to protect the environment, such as desulfurization equipment, safe nuclear power plant design, and emission standards has led to such results as: sulfur dioxide depositions in the CSFR and Poland reaching levels up to eight times higher than in most

Western European countries; the contamination of Poland's main river, the Vistula, by nearly 7,000 tons a day of corrosive salts from coal mines in Silesia; toxic air pollutants in many Soviet cities reaching ten times their (Soviet) maximum permissible level; and the nuclear reactor accident at Chernobyl, which resulted in the contamination of nearly 10,000 square kilometers in

Ukraine. In China as well, the consumption of coal with limited environmental protection has led to airborne particulate levels nearly 15 times higher than in the United States and extremely acidic precipitation. Overall, the environmental problems facing these countries are severe, long-lasting, and not amenable to easy or inexpensive solutions.

**Table 8. World Total Energy Consumption by Type**  
(Quadrillion Btu)

Energy Source	Projection Ranges										
	History		1995			2000			2010		
	1989	1990	Base	Low	High	Base	Low	High	Base	Low	High
<b>Market Economies</b>											
Oil .....	106.3	108.6	119	115	123	127	118	134	140	128	152
Gas .....	44.5	45.9	53	51	55	61	57	63	72	66	78
Coal .....	46.8	49.0	51	49	51	54	51	55	61	55	61
Nuclear .....	16.6	17.4	19	18	19	20	19	20	25	22	26
Other .....	21.1	21.9	25	24	25	28	27	29	34	31	36
<b>Total</b> .....	<b>235.3</b>	<b>242.7</b>	<b>268</b>	<b>266</b>	<b>269</b>	<b>290</b>	<b>286</b>	<b>294</b>	<b>331</b>	<b>324</b>	<b>340</b>
<b>Centrally Planned Economies<sup>a</sup></b>											
Oil .....	28.2	26.5	23	19	27	27	22	31	33	25	41
Gas .....	27.1	27.8	27	26	28	30	28	31	38	32	44
Coal .....	47.2	44.2	50	46	52	54	48	58	62	53	69
Nuclear .....	3.2	3.0	3	3	3	4	3	4	5	4	6
Other .....	4.4	4.4	5	5	5	6	5	6	7	7	8
<b>Total</b> .....	<b>110.2</b>	<b>105.9</b>	<b>109</b>	<b>108</b>	<b>111</b>	<b>120</b>	<b>118</b>	<b>123</b>	<b>144</b>	<b>137</b>	<b>151</b>
<b>World Total</b>											
Oil .....	134.6	135.1	142	137	148	154	144	162	173	158	187
Gas .....	71.6	73.7	80	78	82	90	86	93	111	101	118
Coal .....	94.0	93.2	102	96	103	108	100	111	122	110	128
Nuclear .....	19.8	20.4	22	21	22	24	23	24	29	26	32
Other .....	25.5	26.3	30	29	30	34	32	35	41	37	45
<b>Total</b> .....	<b>345.5</b>	<b>348.6</b>	<b>377</b>	<b>375</b>	<b>379</b>	<b>410</b>	<b>406</b>	<b>416</b>	<b>475</b>	<b>465</b>	<b>486</b>

<sup>a</sup>Includes former, evolving, and current Centrally Planned Economies.

Notes: Energy totals include consumption of biofuels in the United States. Uncertainty ranges for these regional aggregates consist of the base value of each energy source adjusted by the quantity: the square root of the sum of the squared deviations of the respective energy source in the component countries or country groups from their base value. Other totals may not equal sum of components because of independent rounding.

Sources: **History:** Energy Information Administration, *International Energy Annual 1990*, DOE/EIA-0219(90) (1992). **Projections:** Energy Information Administration, World Energy Projection System Spreadsheet, 1992.

**Table 9. World Total Energy Consumption by Region**  
(Quadrillion Btu)

Region/Country	Projection Ranges										
	History		1995			2000			2010		
	1989	1990	Base	Low	High	Base	Low	High	Base	Low	High
<b>Market Economies</b>											
<b>OECD</b>											
United States <sup>a</sup>	84.7	85.0	90.5	89.9	91.3	95.6	93.6	98.1	106.1	102.1	111.6
Canada	10.9	10.8	11.8	11.5	12.1	13.0	12.4	13.5	15.1	14.0	16.2
Japan	17.4	18.2	21.1	20.6	21.6	22.6	21.8	23.4	26.0	24.6	27.5
Europe	58.4	61.9	67.5	66.9	68.2	71.9	70.8	73.0	78.0	76.2	79.8
United Kingdom	9.4	9.1	10.3	9.9	10.7	10.9	10.4	11.5	12.0	11.1	13.0
France	8.6	8.7	10.0	9.6	10.3	10.9	10.4	11.5	12.3	11.4	13.3
Germany <sup>b</sup>	12.2	15.7	16.5	16.4	16.7	17.2	16.9	17.6	18.1	17.5	18.6
Italy	6.8	6.6	7.7	7.4	7.9	8.3	7.9	8.7	9.0	8.4	9.6
Netherlands	3.2	3.4	3.6	3.6	3.7	3.8	3.7	3.9	4.2	4.0	4.5
Other Europe	18.1	18.3	19.5	19.2	19.7	20.7	20.2	21.2	22.4	21.5	23.3
Other OECD	4.9	5.2	5.6	5.4	5.7	5.9	5.6	6.0	6.4	6.0	6.7
<b>Total</b>	<b>176.3</b>	<b>181.0</b>	<b>196.5</b>	<b>195.4</b>	<b>197.7</b>	<b>209.0</b>	<b>206.5</b>	<b>211.9</b>	<b>231.5</b>	<b>226.8</b>	<b>237.6</b>
OPEC	15.3	16.1	18.1	17.7	18.4	20.5	19.4	23.0	25.7	23.0	27.2
Other Developing Countries	43.8	45.7	52.9	51.8	54.1	60.3	58.0	62.8	74.1	69.0	79.6
<b>Total Market Economies</b>	<b>235.3</b>	<b>242.7</b>	<b>267.5</b>	<b>265.9</b>	<b>269.3</b>	<b>289.8</b>	<b>286.2</b>	<b>294.4</b>	<b>331.4</b>	<b>323.8</b>	<b>339.7</b>
<b>Centrally Planned Economies<sup>c</sup></b>											
China	27.8	28.8	37.4	36.3	38.5	42.8	40.8	44.8	52.9	49.0	57.1
Former Soviet Union	58.2	57.1	51.9	51.0	52.8	55.4	53.4	57.5	65.0	59.3	70.8
Other CPE	24.2	19.9	20.1	20.0	20.1	22.2	21.8	22.5	26.0	25.0	27.1
<b>Total</b>	<b>110.2</b>	<b>105.9</b>	<b>109.3</b>	<b>107.9</b>	<b>110.7</b>	<b>120.3</b>	<b>117.5</b>	<b>123.3</b>	<b>144.0</b>	<b>137.0</b>	<b>151.2</b>
<b>World Total</b>	<b>345.5</b>	<b>348.6</b>	<b>376.8</b>	<b>374.7</b>	<b>379.0</b>	<b>410.1</b>	<b>405.6</b>	<b>415.6</b>	<b>475.3</b>	<b>465.1</b>	<b>486.4</b>

<sup>a</sup>Includes the 50 States and the District of Columbia. U.S. Territories are included in "Other OECD." Includes biofuels.

<sup>b</sup>The 1989 amount is for West Germany.

<sup>c</sup>Includes former, evolving, and current Centrally Planned Economies.

OECD = Organization for Economic Cooperation and Development.

OPEC = Organization of Petroleum Exporting Countries.

Notes: High and low range values for Europe and the 4 regional totals are not equal to the sum of the component countries or country groups but consist of the base value adjusted by the quantity: the square root of the sum of the squared deviations of the respective component countries or country groups from their base value. Other totals may not equal sum of components because of independent rounding.

Sources: **History:** Energy Information Administration, *International Energy Annual 1990*, DOE/EIA-0219(90) (1992). **Projections:** Energy Information Administration, *Annual Energy Outlook 1992*, DOE/EIA-0383(92) (1992); *Oil Market Simulation Model User's Manual* DOE/EIA-MO28(92) (1992); and World Energy Projection System Spreadsheet, 1992.

**Table 10. World Natural Gas Consumption**  
(Trillion Cubic Feet)

Region/Country	Projection Ranges										
	History		1995			2000			2010		
	1989	1990	Base	Low	High	Base	Low	High	Base	Low	High
<b>Market Economies</b>											
<b>OECD</b>											
United States <sup>a</sup>	18.8	18.7	20.5	20.3	20.7	21.9	21.3	22.5	22.7	21.4	23.5
Canada	2.4	2.5	2.5	2.4	2.5	2.7	2.4	2.9	3.0	2.2	3.6
Japan	1.6	1.7	2.0	1.7	2.5	2.4	1.8	3.0	3.6	2.5	4.6
Europe	9.6	10.6	13.7	12.7	14.7	16.6	14.9	18.3	20.0	17.4	22.4
United Kingdom	2.0	2.0	2.9	2.3	3.5	3.4	2.5	4.3	4.5	3.0	5.7
France	1.1	1.1	1.5	1.2	1.8	2.3	1.7	2.9	2.9	2.0	3.8
Germany <sup>b</sup>	2.3	3.0	4.3	3.6	4.9	4.8	3.7	5.8	5.1	3.5	6.3
Italy	1.6	1.7	1.8	1.6	2.1	2.2	1.7	2.7	2.6	1.8	3.4
Netherlands	1.4	1.5	1.6	1.4	1.7	1.8	1.5	2.0	1.9	1.4	2.2
Other Europe	1.2	1.3	1.6	1.2	1.9	2.2	1.6	2.7	3.1	2.2	4.0
Other OECD	0.7	0.7	0.8	0.6	1.0	0.9	0.7	1.1	1.0	0.7	1.2
<b>Total</b>	<b>33.0</b>	<b>34.3</b>	<b>39.5</b>	<b>38.4</b>	<b>40.7</b>	<b>44.4</b>	<b>42.5</b>	<b>46.3</b>	<b>50.2</b>	<b>46.9</b>	<b>53.0</b>
OPEC	5.6	5.8	6.5	5.9	6.9	7.4	5.9	8.6	9.1	6.0	11.3
Other Developing Countries	4.7	4.9	6.2	5.0	7.6	7.7	5.4	10.3	11.7	7.6	15.8
<b>Total Market Economies</b>	<b>43.3</b>	<b>45.0</b>	<b>52.2</b>	<b>50.4</b>	<b>54.0</b>	<b>59.4</b>	<b>56.1</b>	<b>62.7</b>	<b>71.0</b>	<b>64.9</b>	<b>77.0</b>
<b>Centrally Planned Economies<sup>c</sup></b>											
China	0.5	0.5	0.7	0.7	0.8	1.0	0.9	1.1	1.3	1.2	1.5
Former Soviet Union	24.5	25.5	24.5	23.8	25.2	25.4	23.5	27.4	31.9	26.0	37.7
Other CPE	3.9	3.4	3.5	3.4	3.6	4.8	4.4	5.2	7.0	5.8	8.1
<b>Total</b>	<b>28.9</b>	<b>29.4</b>	<b>28.7</b>	<b>28.0</b>	<b>29.4</b>	<b>31.2</b>	<b>29.2</b>	<b>33.3</b>	<b>40.2</b>	<b>34.2</b>	<b>46.1</b>
<b>World Total</b>	<b>72.3</b>	<b>74.4</b>	<b>80.9</b>	<b>79.0</b>	<b>82.9</b>	<b>90.6</b>	<b>86.8</b>	<b>94.5</b>	<b>111.1</b>	<b>102.6</b>	<b>119.6</b>

<sup>a</sup>Includes the 50 States and the District of Columbia. U.S. Territories are included in "Other OECD."

<sup>b</sup>The 1989 amount is for West Germany.

<sup>c</sup>Includes former, evolving, and current Centrally Planned Economies.

OECD = Organization for Economic Cooperation and Development.

OPEC = Organization of Petroleum Exporting Countries.

Notes: High and low range values for Europe and the 4 regional totals are not equal to the sum of the component countries or country groups but consist of the base value adjusted by the quantity: the square root of the sum of the squared deviations of the respective component countries or country groups from their base value. Other totals may not equal sum of components because of independent rounding.

Sources: **History:** Energy Information Administration, *International Energy Annual 1990*, DOE/EIA-0219(90) (1992); and *Monthly Energy Review*, DOE/EIA-0035(91/12) (1991). **Projections:** Energy Information Administration, *Annual Energy Outlook 1992* DOE/EIA 0383(92) (1992) and World Energy Projection System Spreadsheet, 1992.

**Table 11. World Coal Consumption**  
(Million Short Tons)

Region/Country	Projection Ranges										
	History		1995			2000			2010		
	1989	1990	Base	Low	High	Base	Low	High	Base	Low	High
<b>Market Economies</b>											
<b>OECD</b>											
United States <sup>a</sup>	891	895	934	931	936	993	988	997	1,213	1,131	1,269
Canada	63	57	65	59	72	79	67	90	86	69	103
Japan	121	122	128	117	144	130	113	153	136	114	163
Europe	632	893	865	814	921	846	773	927	826	732	927
United Kingdom	127	112	114	103	126	112	95	129	109	88	131
France	35	34	34	30	37	28	24	32	24	19	29
Germany <sup>b</sup>	210	492	441	397	485	406	345	467	367	294	441
Italy	24	24	31	28	34	38	32	44	40	32	48
Netherlands	13	16	17	15	19	18	15	20	19	15	23
Other Europe	224	216	228	205	259	244	208	294	266	213	332
Other OECD	107	120	125	115	134	128	112	144	131	108	152
<b>Total</b>	<b>1,813</b>	<b>2,087</b>	<b>2,117</b>	<b>2,064</b>	<b>2,176</b>	<b>2,176</b>	<b>2,098</b>	<b>2,262</b>	<b>2,392</b>	<b>2,262</b>	<b>2,514</b>
OPEC	7	7	11	9	12	11	9	13	14	11	17
Other Developing Countries	553	557	583	558	613	653	580	737	723	603	796
<b>Total Market Economies</b>	<b>2,373</b>	<b>2,651</b>	<b>2,711</b>	<b>2,652</b>	<b>2,777</b>	<b>2,840</b>	<b>2,733</b>	<b>2,960</b>	<b>3,129</b>	<b>2,952</b>	<b>3,271</b>
<b>Centrally Planned Economies<sup>c</sup></b>											
China	1,147	1,205	1,363	1,227	1,499	1,553	1,320	1,786	2,005	1,604	2,406
Former Soviet Union	729	661	646	582	711	648	551	746	663	530	795
Other CPE	1,023	655	654	589	720	647	550	743	634	507	761
<b>Total</b>	<b>2,899</b>	<b>2,521</b>	<b>2,664</b>	<b>2,499</b>	<b>2,828</b>	<b>2,848</b>	<b>2,577</b>	<b>3,118</b>	<b>3,302</b>	<b>2,861</b>	<b>3,743</b>
<b>World Total</b>	<b>5,272</b>	<b>5,171</b>	<b>5,375</b>	<b>5,200</b>	<b>5,552</b>	<b>5,687</b>	<b>5,397</b>	<b>5,984</b>	<b>6,431</b>	<b>5,956</b>	<b>6,894</b>

<sup>a</sup>Includes the 50 States and the District of Columbia. U.S. Territories are included in "Other OECD."

<sup>b</sup>The 1989 amount is for West Germany.

<sup>c</sup>Includes former, evolving, and current Centrally Planned Economies.

OECD = Organization for Economic Cooperation and Development.

OPEC = Organization of Petroleum Exporting Countries.

Notes: High and low range values for Europe and the 4 regional totals are not equal to the sum of the component countries or country groups but consist of the base value adjusted by the quantity: the square root of the sum of the squared deviations of the respective component countries or country groups from their base value. Other totals may not equal sum of the components because of independent rounding.

Sources: **History:** Energy Information Administration, *International Energy Annual 1990*, DOE/EIA-0219(90) (1992) and *Monthly Energy Review*, DOE/EIA-0035(91/12) (1991). **Projections:** Energy Information Administration, *Annual Energy Outlook 1992*, DOE/EIA-0383(92) (1992) and World Energy Projection System Spreadsheet, 1992.

**Table 12. World Net Nuclear Energy Consumption**  
(Billion Kilowatthours)

Region/Country	Projection Ranges										
	History		1995			2000			2010		
	1989	1990	Base	Low	High	Base	Low	High	Base	Low	High
<b>Market Economies</b>											
<b>OECD</b>											
United States <sup>a</sup>	529	577	600	599	600	639	633	645	634	619	690
Canada	75	69	94	94	94	96	96	96	120	120	163
Japan	175	182	261	223	261	279	264	279	419	338	419
Europe	693	699	722	712	722	764	749	764	882	794	970
United Kingdom	81	76	65	65	65	67	61	67	61	53	68
France	240	248	288	288	288	315	315	315	390	356	424
Germany <sup>b</sup>	144	144	137	137	137	139	139	139	171	157	185
Italy	21	22	22	22	22	23	23	23	30	27	34
Netherlands	6	5	6	6	6	6	6	6	7	5	9
Other Europe	201	204	204	195	204	214	205	214	223	195	251
Other OECD	0	0	0	0	0	0	0	0	0	0	0
<b>Total</b>	<b>1,472</b>	<b>1,527</b>	<b>1,677</b>	<b>1,628</b>	<b>1,677</b>	<b>1,779</b>	<b>1,742</b>	<b>1,784</b>	<b>2,055</b>	<b>1,871</b>	<b>2,242</b>
OPEC	0	0	0	0	0	0	0	0	0	0	0
Other Developing Countries	93	107	119	106	119	133	124	133	240	198	282
<b>Total Market Economies</b>	<b>1,565</b>	<b>1,634</b>	<b>1,796</b>	<b>1,734</b>	<b>1,796</b>	<b>1,912</b>	<b>1,866</b>	<b>1,917</b>	<b>2,295</b>	<b>2,069</b>	<b>2,524</b>
<b>Centrally Planned Economies<sup>c</sup></b>											
China	0	0	13	7	13	13	7	16	18	13	24
Former Soviet Union	208	207	210	205	216	250	237	263	296	245	350
Other CPE	71	58	67	61	70	76	63	82	109	97	120
<b>Total</b>	<b>278</b>	<b>264</b>	<b>290</b>	<b>273</b>	<b>299</b>	<b>339</b>	<b>308</b>	<b>361</b>	<b>423</b>	<b>355</b>	<b>494</b>
<b>World Total</b>	<b>1,843</b>	<b>1,898</b>	<b>2,085</b>	<b>2,007</b>	<b>2,095</b>	<b>2,251</b>	<b>2,174</b>	<b>2,278</b>	<b>2,718</b>	<b>2,424</b>	<b>3,018</b>

<sup>a</sup>Includes the 50 States and the District of Columbia. U.S. Territories are included in "Other OECD."

<sup>b</sup>The 1989 amount is for West Germany.

<sup>c</sup>Includes former, evolving, and current 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.

Sources: **History:** Energy Information Administration, *International Energy Annual 1990*, DOE/EIA-0219(90) (1992) and *Monthly Energy Review*, DOE/EIA-0035(91/12) (1991). **Projections:** Energy Information Administration, *Annual Energy Outlook 1992*, DOE/EIA-0383(92) (1992) and World Energy Projection System Spreadsheet, 1992.



**Table 13. World Hydropower and Geothermal Energy Consumption**  
(Quadrillion Btu)

Region/Country	Projection Ranges										
	History		1995			2000			2010		
	1989	1990	Base	Low	High	Base	Low	High	Base	Low	High
<b>Market Economies</b>											
<b>OECD</b>											
United States <sup>a</sup>	6.4	6.6	7.9	7.9	8.0	9.0	8.8	9.2	11.0	10.5	11.6
Canada	2.9	3.0	3.3	3.3	3.4	4.0	3.8	4.2	5.3	4.8	5.9
Japan	1.0	1.0	1.2	1.2	1.2	1.4	1.3	1.4	1.9	1.7	2.0
Europe	4.5	4.5	4.8	4.6	4.9	5.0	4.7	5.3	5.7	5.1	6.3
United Kingdom	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.2
France	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.7
Germany <sup>b</sup>	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5
Italy	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.7
Netherlands	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.3
Other Europe	3.1	3.1	3.2	3.2	3.3	3.4	3.2	3.5	3.6	3.2	4.0
Other OECD	0.4	0.4	0.5	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.7
<b>Total</b>	<b>15.2</b>	<b>15.6</b>	<b>17.7</b>	<b>17.4</b>	<b>17.9</b>	<b>19.9</b>	<b>19.1</b>	<b>20.6</b>	<b>24.5</b>	<b>22.5</b>	<b>26.4</b>
OPEC	0.6	0.6	0.8	0.8	0.8	0.9	0.8	0.9	1.1	1.0	1.2
Other Developing Countries	5.4	5.7	6.4	6.3	6.6	7.2	6.8	7.5	8.0	7.1	8.8
<b>Total Market Economies</b>	<b>21.2</b>	<b>21.9</b>	<b>24.9</b>	<b>24.4</b>	<b>25.3</b>	<b>27.9</b>	<b>26.7</b>	<b>29.0</b>	<b>33.6</b>	<b>30.7</b>	<b>36.5</b>
<b>Centrally Planned Economies<sup>c</sup></b>											
China	1.1	1.2	1.9	1.8	1.9	2.5	2.3	2.6	4.2	3.7	4.6
Former Soviet Union	2.3	2.2	2.1	2.1	2.2	2.1	2.0	2.2	2.2	2.0	2.4
Other CPE	1.0	1.0	1.0	1.0	1.0	1.1	1.0	1.1	1.0	0.9	1.2
<b>Total</b>	<b>4.4</b>	<b>4.4</b>	<b>5.0</b>	<b>4.9</b>	<b>5.1</b>	<b>5.6</b>	<b>5.3</b>	<b>5.9</b>	<b>7.4</b>	<b>6.6</b>	<b>8.2</b>
<b>World Total</b>	<b>25.5</b>	<b>26.3</b>	<b>29.9</b>	<b>29.3</b>	<b>30.5</b>	<b>33.5</b>	<b>32.1</b>	<b>34.9</b>	<b>41.0</b>	<b>37.3</b>	<b>44.6</b>

<sup>a</sup>Includes the 50 States and the District of Columbia. U.S. Territories are included in "Other OECD."

<sup>b</sup>The 1989 amount is for West Germany.

<sup>c</sup>Includes former, evolving, and current Centrally Planned Economies.

OECD = Organization for Economic Cooperation and Development.

OPEC = Organization of Petroleum Exporting Countries.

Notes: U.S. amounts also include energy from solar, wind, and biofuels. Totals may not equal sum of components because of independent rounding.

Sources: **History:** Energy Information Administration, *International Energy Annual 1990*, DOE/EIA-0219(90) (1992). **Projections:** Energy Information Administration, *Annual Energy Outlook 1992*, DOE/EIA-0383(92) (1992) and World Energy Projection System Spreadsheet, 1992.

## The Centrally Planned Economies

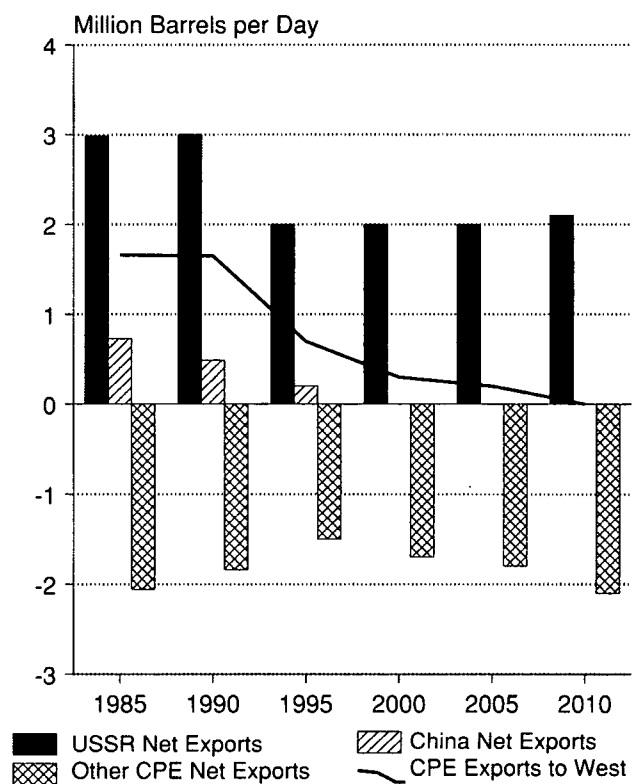
Revolutionary events unfolded in Eastern Europe and the former Soviet Union in 1991. Among the most significant were the dissolution of the Warsaw Pact in June, the dismantling of the Council for Mutual Economic Assistance (Comecon) in July, the failed Soviet coup attempt in August, the subsequent collapse of the Soviet Communist Party after more than 70 years in power, the dissolution of the Soviet Union, and the formation of the new Commonwealth of Independent States.

The long-term implications of these events will take years to sort out. In the short run, tensions between East and West have eased, but ethnic tensions within the East have increased. Economic and political relations have been fundamentally altered, with important implications for the United States and the West in general. Overall, these changes will have a major influence on future world economic relationships, including the production, consumption, distribution, and pricing of all forms of energy resources. The former Soviet Union, for instance, is the world's largest energy producer. Traditionally, the Soviet Union represented a major net exporter of oil and natural gas, supplying these fuels at subsidized prices to its Eastern European trading partners. Within the former Soviet Union, Russia was the major supplier of oil and natural gas to the other former Soviet republics. The political and economic collapse of the Soviet Union, however, has thrown many of these relationships into doubt (Figures 13 and 14).

### Oil Production

The former Soviet Union, also referred to as "Soviet," has been the largest oil producing country in the world since 1974, when it surpassed the United States. In 1990, total Soviet oil (including all liquids) production was 11.4 million barrels per day, accounting for 17 percent of the world's total. Events of the past year have thrown the future status of this production into doubt. Indications are that total 1991 production averaged around 1 million barrels per day less than in 1990, with a similar decline possible in 1992. The longer term oil production outlook is even more uncertain, with a wide

**Figure 13. CPE Regional Net Exports of Petroleum, 1985-2010**

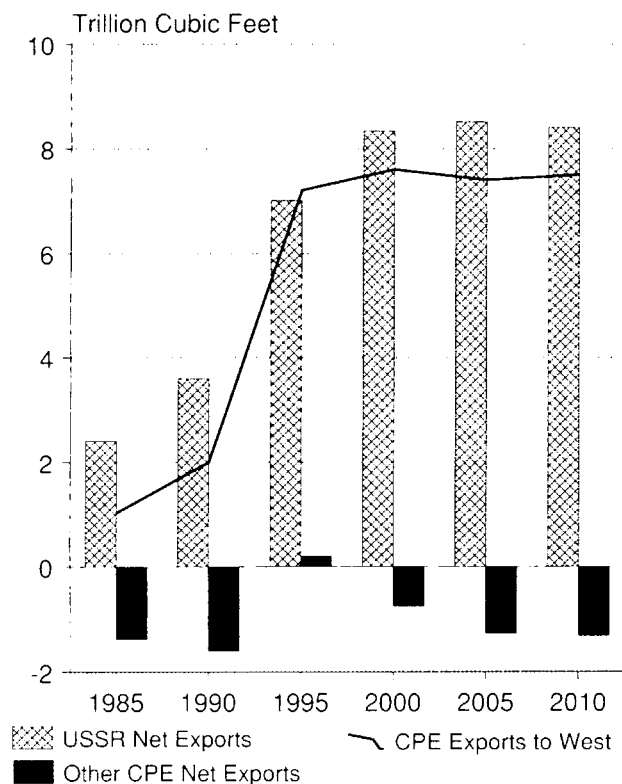


Note: CPE's include former, evolving, and current Centrally Planned Economies.

Sources: **History:** Energy Information Administration, *International Energy Annual 1990*, DOE/EIA-0219(90). **Projections:** Table 2.

range of outcomes possible (Table 4). Part of this uncertainty stems from questions about the size of Soviet oil reserves. The current estimate of 57 billion barrels, equivalent to only 15 years of reserves at 1991 production rates, is roughly comparable to estimated reserves in Mexico, which produced only 3 million barrels per day in 1990. Comparisons such as this have led to suggestions that Soviet oil reserves may be significantly underestimated. A more definitive answer could become available as outside oil companies conduct their own assessments.

**Figure 14. CPE Regional Net Exports of Natural Gas, 1985-2010**



Note: CPE's include former, evolving, and current Centrally Planned Economies.

Sources: **History:** Energy Information Administration, *International Energy Annual 1990*, DOE/EIA-0219(90). **Projections:** Table 10 and World Energy Projection System Spreadsheet 1992.

Uncertainty also exists regarding the pace of reforms in the oil industry and the economy in general. Problems in the Soviet oil industry are well documented. They include the general deterioration of important infrastructure, the inability to distribute needed supplies, inadequate quality control on production equipment combined with antiquated technology, the inordinate use of reservoir-damaging techniques such as waterflooding, an irrational pricing system, and low productivity levels exacerbated by discontent among oil workers. In addition, the exploitation of many easily accessible reservoirs has left the majority of Soviet oil reserves concentrated in relatively remote, inaccessible areas.

It is unlikely that the decline in Soviet oil output can be reversed without a massive infusion of financial and technological resources into the oil and oil service industries, which already consumed 20 percent of Soviet investment expenditures in 1988. Faced with an economic and political crisis and the need to shift additional investment funds into consumer goods, the Soviet Union cut back funding for the oil industry in 1990, and oil production plummeted. Until the Soviet economy emerges from its current crisis, these resources will have to come from elsewhere. This leaves the outlook for future Soviet oil production clouded by much uncertainty. It is assumed here that oil production in the former Soviet Union will stabilize by 2000 with the help of investment from outside companies, and will increase steadily thereafter to between 9 million barrels per day and 13 million barrels per day by 2010 (Table 4).

In order to achieve these levels, the former Soviet Union has already sought assistance from various Western and other countries, including Japan. The degree to which such assistance will be forthcoming and the rate at which it leads to increased oil production is highly uncertain. The form which it will take is also uncertain. Initially, outside companies have been awarded production rights, and some joint ventures between foreign oil companies and Soviet oil concerns have been formed. This approach could change, however. Some awards have been canceled already in favor of competitive bidding. In the future, joint ventures may be bypassed in favor of other arrangements, such as the Saudi model where outside companies are hired as contractors instead of as joint venture partners. Currently, foreign investment in the former Soviet Union is being stymied by a variety of issues, including a battle among the former republics over property rights. There are also many jurisdictional issues to sort out as authority over Soviet oil production shifts from the former all-Union Ministries to republican and local authorities. The absence of a "mineral resources code" defining these rights poses a major impediment to potential investors.

Events in the other current and former Centrally Planned Economies, henceforth called simply the CPE's, were largely overshadowed in 1990 by the dramatic changes in the Soviet Union. Although Eastern Europe currently produces over 300,000 barrels per day of oil, mainly in Romania, Albania, and Yugoslavia, this production has declined gradually during the last decade as fields have matured and production techniques have remained antiquated.<sup>2</sup> While reserves

<sup>2</sup>In this report, East Germany is excluded from Eastern Europe as of 1990.

are relatively small and no new large fields are expected to be found, production should stabilize with the aid of western companies that are now beginning to do business in the region. Oil production in China is currently near 2.8 million barrels per day. This production is forecast to grow to 3.7 million barrels per day by 2010.

## Oil Demand

Soviet oil consumption is expected to drop and Eastern European consumption is expected to stagnate at a time when other regions of the world are expected to increase consumption (Table 3), mainly in response to the relatively low world oil prices over the next 5 years. A primary reason for this decline in oil consumption in the CPE's is the negative economic growth rates expected for these countries over the next few years (Table 5). A second reason is the ongoing switch from subsidized prices to market-determined prices. This *IEO92* assumes that the economic situation in the former Soviet Union and Eastern Europe will stabilize sometime after 1995, but only after further declines in gross domestic product (GDP) of 15 to 20 percent. This economic contraction should result in a decrease in oil demand by as much as 2 million barrels per day for the region as a whole. Beginning in 1995, however, economic growth should resume in the former Soviet Union, averaging 1.5 percent per year through 2010. Eastern Europe's economy is expected to grow as well, but at a faster rate of nearly 4 percent during the same period as a result of economic and political reforms now underway. As with everything pertaining to this region, these economic growth forecasts are highly uncertain.

With the anticipated economic expansion after 1995, oil consumption is likely to increase in the former Soviet Union to almost 9 million barrels per day, and in Eastern Europe to about 2.4 million barrels per day, by 2010. Much of this increase will occur in the transportation sector, as pent-up consumer demand for automobiles is met. This demand increase could offset energy efficiency gains expected in the industrial sector, with the overall result that oil consumption should rise slowly as reforms take place and economic conditions improve. A major trend in the region away from heavy industry and military-industrial production towards light industry and civilian production should also result in downward pressure on oil demand, particularly for light products like gasoline. Finally, the shift to market pricing for oil should lead to higher prices which would also exert downward pressure on oil demand.

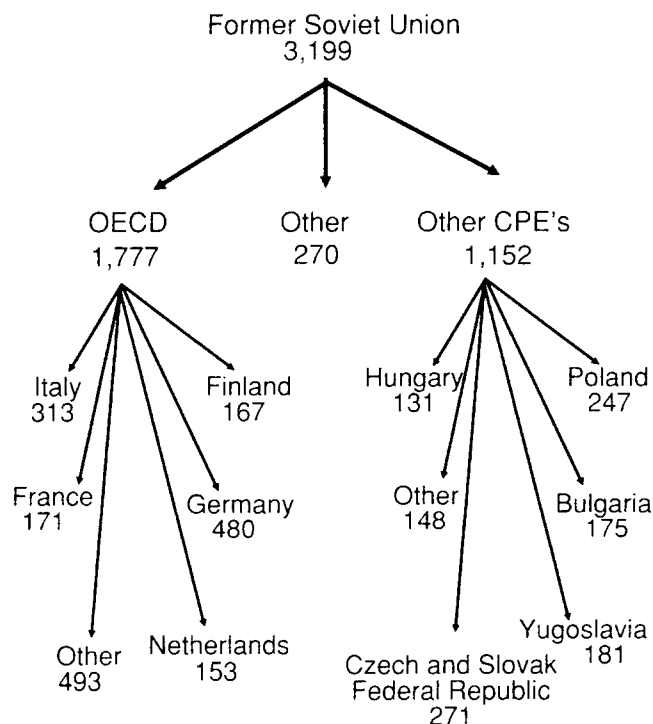
## Oil Trade

Dissolution of the Council for Mutual Economic Assistance (Comecon), which formally linked the economies of Eastern Europe and the Soviet Union, holds the potential for dramatic changes in trade flows and prices in all sectors of the regional economy. After nearly 50 years of economic and political integration, however, these changes will not take place overnight. At present, it appears that Eastern Europe will remain dependent on oil imports from the former Soviet Union for some time. As a whole, Eastern Europe depends heavily on the former Soviet Union for its oil needs (Figure 15), although this dependence has decreased over the last 3 years as the region has diversified to include supplies from the Middle East and North Africa (Figure 16). Even this supply is potentially vulnerable, however, as evidenced by the war with Iraq. Another disruption to these supplies has come from the closure of the Adria pipeline since mid-September due to the civil war in Yugoslavia. This pipeline runs from the Adriatic coast of Yugoslavia near Rijeka, across war-torn Croatia, and then into land-locked Hungary, and has the capacity to supply over 200,000 barrels per day of oil to refineries in Yugoslavia, the Czech and Slovak Federal Republic, and Hungary. The vulnerability of this pipeline to disruption illustrates the need for further diversification of supply sources into the region. Overall, however, Eastern Europe will likely remain heavily dependent on the former Soviet Union for years to come.

## Natural Gas Overview

Any discussion of natural gas in the CPE's must focus on the former Soviet Union, which contains the largest natural gas reserves in the world. The former Soviet Union accounts for about 40 percent of the world's total natural gas reserves. Current reserve estimates are around 1,750 trillion cubic feet, with potential resources estimated to be considerably higher. Between 80 and 90 percent of these reserves are contained in Russia. The largest fields, particularly Urengoi (7.6 trillion cubic feet) and Yamburg (4.5 trillion cubic feet) are located in the Tyumen Province of Western Siberia, but there are many giant fields elsewhere in Russia, as well as in other former Soviet republics. Huge new reserves, on the order of 350 trillion cubic feet or more, have been discovered in the remote Arctic regions of the Yamal Peninsula and the Barents Sea. The huge natural gas resource base has helped make the former Soviet Union the largest producer and consumer of natural gas in the

**Figure 15. Soviet Oil Exports by Destination, 1990**  
(Thousand Barrels per Day)



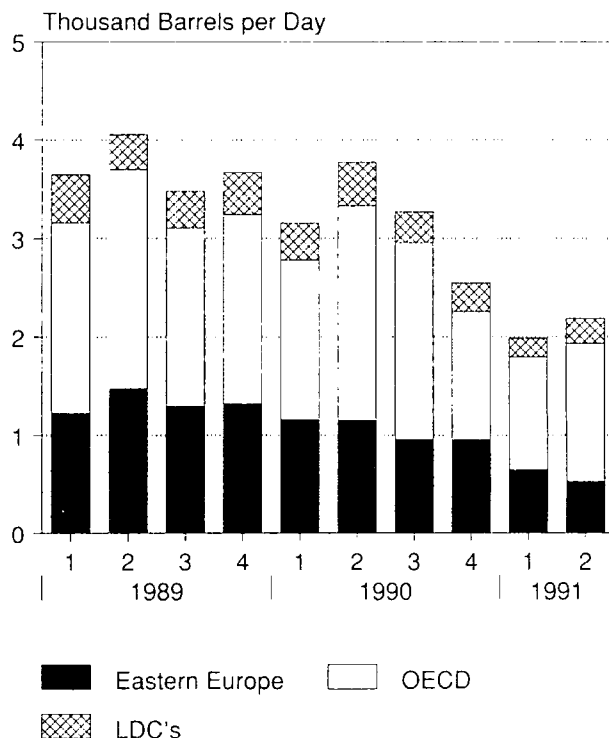
Note: CPE's include former, evolving, and current Centrally Planned Economies.

Source: PlanEcon, Inc., *PlanEcon Energy Report*, December 1991, Washington, DC.

world. In 1990, the country produced over 29 trillion cubic feet, accounting for nearly 40 percent of the world total, and placing it over 10 trillion cubic feet ahead of the second largest producer—the United States. Of this production, the Soviet Union exported 3.6 trillion cubic feet in that year, or 35 percent of world natural gas exports. These exports went to Western Europe (2.0 trillion cubic feet) and Eastern Europe (1.6 trillion cubic feet), accounting for over 25 percent of Europe's natural gas consumption. Finally, the former Soviet Union consumed the greatest amount of natural gas (25.5 trillion cubic feet) in the world in 1990—over one-third of worldwide demand.

In contrast, the other CPE's produced less than 3 trillion cubic feet of gas, consumed around 4 trillion cubic feet in 1990, and contain proven reserves of only about 50 trillion cubic feet (less than 3 percent of Soviet reserves). Thus, the future of natural gas in the CPE's is essentially the future of natural gas in the former Soviet Union.

**Figure 16. Soviet Oil Exports by Quarter, 1989-1991**



Source: PlanEcon, Inc., *PlanEcon Energy Report*, December 1991, Washington, DC.

## Natural Gas Consumption

Natural gas furnishes a greater share of the former Soviet Union's primary energy demand than any other fuel. In the future, however, this share is projected to remain level, or perhaps even to decrease slightly. The collapse of the Soviet's ambitious nuclear power construction program has placed additional demands on natural gas as a source for electricity generation. Overall, natural gas currently accounts for about 42 percent of energy consumption in the former Soviet Union. This represents an enormous increase from 1980, when only 27 percent of Soviet energy demand was met by natural gas, and results from a policy of displacing other fuels with natural gas. Further displacement will become increasingly difficult between now and 2010. The growth in natural gas share should slow considerably, reaching only around 44 percent in 2010. Two major factors are expected to contribute to this slower growth trend: (1) a structural shift away from the gas-intensive heavy industry sector and (2) an

overall economic downturn, which will tend to slow the growth in natural gas consumption throughout the economy.

### ***Natural Gas Production***

In terms of natural gas production in the former Soviet Union, the outlook is relatively promising. Given the huge reserve base, located primarily in Russia, large increases in natural gas production by 2010 are possible—perhaps to as high as 40 trillion cubic feet. Much of this production increase would have to come from new fields, however, located in relatively remote and difficult areas necessitating massive levels of investment, which may not be forthcoming. In general, the period of “easy gas” is rapidly coming to an end, which implies rising costs of production. On the positive side, the current Soviet gas industry is relatively young and technologically less sophisticated than the oil industry, and consequently may not require large amounts of money to maintain current levels of production. Investment resources can therefore be concentrated on increasing production, rather than on repair or replacement of current equipment. Furthermore, the gas industry is less labor intensive than other fuels, and thus less vulnerable to labor disruptions. However, many issues and problems must still be resolved in order to successfully exploit the enormous gas resource base in the former Soviet Union. One important issue to be resolved involves the organization of the gas production industry. Currently, Soviet gas production centers on the state gas concern, Gazprom. This highly centralized organization accounts for over 90 percent of gas production in the former Soviet Union. However, the breakup of the Soviet Union throws the status of Gazprom into doubt.

### ***Natural Gas Exports***

A relatively optimistic outlook for Soviet natural gas production, combined with a generally flat forecast for consumption, could result in considerable increases in exports of natural gas from the former Soviet Union, perhaps to levels as high as 8 trillion cubic feet by 2010. The incentive for expanding these exports is obvious since revenues from sales of oil and natural gas provide nearly 40 percent of Soviet hard currency earnings. It is assumed that markets for such high levels of exports will exist, both in current Soviet gas export markets in Europe as well as in new areas, particularly the Far East. Such increased levels of natural gas exports, however, would require the construction of thousands of miles of pipeline, demanding large amounts of capital. There is great uncertainty as to whether such investments will be forthcoming. At present, there are

six major export pipeline systems in the former Soviet Union. Progress, Soyuz, Brotherhood, West Ukraine, and Northern Lights all pass through Ukraine, into the Czech and Slovak Federal Republic, and on to other parts of Eastern and Western Europe. The Shebelinka-Izmail Pipeline, which traverses southern Ukraine, enters Romania at Izmail, and continues on to Bulgaria. These pipelines all pass through Ukraine, now an independent nation, but carry natural gas almost exclusively from Russia, another independent state, which may have ramifications for future prospects for Soviet natural gas exports. Furthermore, many of these pipelines are in desperate need of repair—a situation exacerbated by the high sulfur content of much Soviet natural gas.

## **Coal Overview**

Unlike oil and natural gas, coal resources in the CPE's are not centered totally in the former Soviet Union. In fact, the largest coal reserves in the CPE's may be located in China, although there is great uncertainty surrounding estimates of China's reserves. The former Soviet Union, China, and the United States possess the largest coal reserves in the world, together accounting for more than two-thirds of total world reserves. In 1989, China's production of anthracite and bituminous coal combined was the highest in the world, accounting for 29 percent of total world production. In the same year, the Soviet Union ranked third behind the United States, with 15 percent of world coal production, while Poland ranked fifth, with 5 percent. Combined, the CPE's accounted for nearly half the world's coal production in 1990. On the demand side, the CPE's consumed nearly 45 trillion British thermal units (Btu) of coal in 1990, accounting for about 43 percent of total world coal consumption in that year. Of this total, China consumed 22 trillion Btu, the Soviet Union 11 trillion, and the other CPE's (mainly Poland, and the Czech and Slovak Federal Republic) around 9 trillion. Finally, in terms of coal trade, the Soviet Union and Poland were major players in 1989, supplying 8 percent and 7 percent, respectively, of the world's total exports. These exports went almost exclusively to Eastern and Western Europe. Despite its high level of production, China is a relatively minor exporter of coal.

### ***Coal Consumption***

China, with its huge coal reserves, has a coal-driven economy. Overall, coal accounts for about 77 percent of primary energy consumption in China, with 99 percent of production supplying the domestic market. This reliance on coal is projected to decrease only slightly by

2010, to around 75 percent. Usage is highly inefficient, due to controls on the domestic price of coal. It also contributes to environmental problems, including severe air pollution in many Chinese cities and acid rain.

Coal consumption in the former **Soviet Union** amounted to 661 million short tons in 1990, accounting for around 20 percent of primary energy consumption. It is likely that this share will decrease by 2010, however, to around 18 percent, to be replaced largely by natural gas.

**Eastern Europe** relied on coal for around 53 percent of its primary energy demand in 1990. This reliance should decrease over time, to around 40 percent by 2010. Environmental problems associated with coal consumption are a major factor working against coal, but there are other considerations as well. In the past, artificially low energy prices encouraged wasteful use of coal. As the countries of Eastern Europe move towards market mechanisms, the price of coal should rise, leading to improvements in energy efficiency, and consumption of coal should fall.

### ***Coal Production and Trade***

**China** produced 1.2 billion short tons of hard coal in 1990—the first country to exceed 1 billion tons of production. Coal is produced mainly in northeastern China, from two distinct classes of mines: large state-controlled enterprises and small, locally controlled (or private) mines. The development of a significant export industry has been impeded by domestic demand requirements and the absence of essential infrastructure development (i.e., mechanized port facilities, electrified rail corridors, preparation plants). Foreign participation in this industry was disrupted by political turmoil in 1989, and its future remains uncertain. China currently exports about 300 trillion Btu of coal, mainly to Japan, Hong Kong, and South Korea.

The former **Soviet Union** produced 554 million short tons of hard coal and 207 million short tons of brown coal, in 1989. This level declined substantially in 1990, however, due largely to a coal miners' strike and general worker discontent. Coal production is centered primarily in western Siberia, in the Kuzbass and Yakut fields; in southern Siberia, in the Kuznetsk and Kansk-Achinsk basins; in the Donetsk basin of the southern Ukraine; in European Russia, mainly the Moscow Basin; and Kazakhstan, in Karaganda and Ekibastuz. The future of Soviet coal production is uncertain and faced with many difficulties. For one thing, production and transportation costs are very high, especially compared

to natural gas. Other problems facing the coal industry revolve around associated environmental problems, and the difficulties involved in transporting and utilizing coal relative to natural gas.

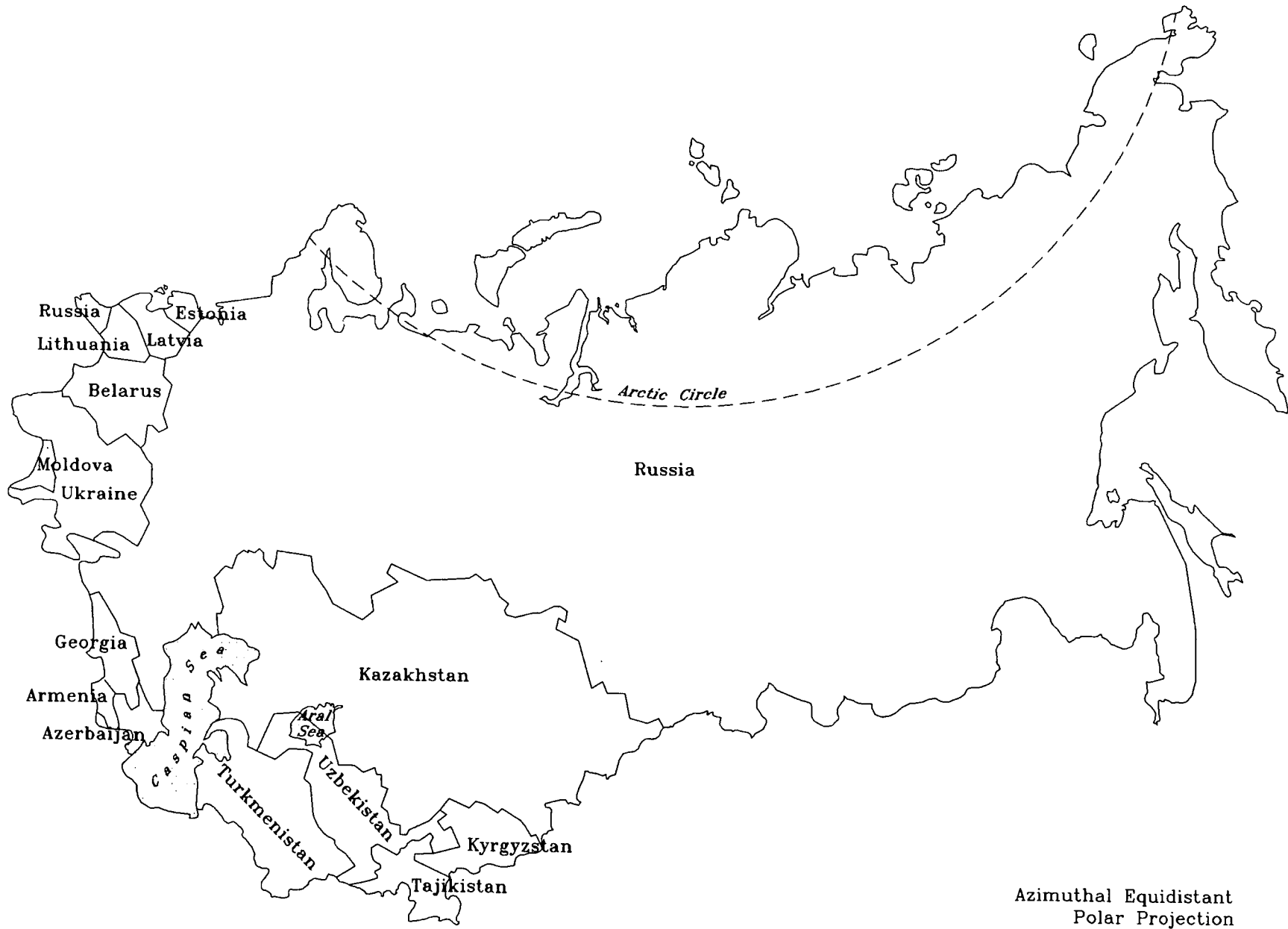
**Eastern Europe**, including East Germany, produced around 949 million short tons of coal in 1989. Most of this coal (714 million short tons) was lignite; the rest (235 million short tons) was hard coal. Most of the hard coal (196 million short tons) was produced in Poland, while most of the brown coal (332 million short tons) came from East Germany. Traditionally, the East European countries have traded mostly among themselves. With the dissolution of Comecon and the switch to market pricing, however, this pattern may change in the future.

## **Former Soviet Republics**

With the demise of the Soviet Union, increased attention has been focused on individual former republics, which are now in the process of becoming independent nations (Figure 17). Despite the political breakup of the Soviet Union, however, there continues to be a high degree of economic interdependence among these new nations. As discussed below, an abrupt break in economic relations could result in the disruption for the smaller republics of vital imports of raw materials, including energy supplies, and the loss of major export markets for their agricultural and manufactured goods. Russia, on the other hand, would suffer from the loss of export outlets for its oil and gas, since the new country contains only one major oil port, Novorossiisk on the Black Sea. In addition, Russia's major oil and gas pipelines to export markets in Europe are potentially vulnerable to disruption, since they traverse the territory of Ukraine, now an independent state. Finally, Russia is also dependent on the other former republics for energy production equipment (e.g., oil production equipment from Azerbaijan). Given such potential for mutual economic destruction, the rational course of action would be for the former Soviet republics to cooperate and maintain economic ties.

The former Soviet republics vary widely in their energy production and consumption patterns (Table 14). In general, however, they are all relatively wasteful in their energy use. In 1990, for instance, the 15 former Soviet republics consumed 28,000 quadrillion Btu of energy per constant 1990 dollar of gross domestic product. In comparison, the United States consumed about 15,000 quadrillion Btu per 1990 dollar in the same

Figure 17. The Former Soviet Union

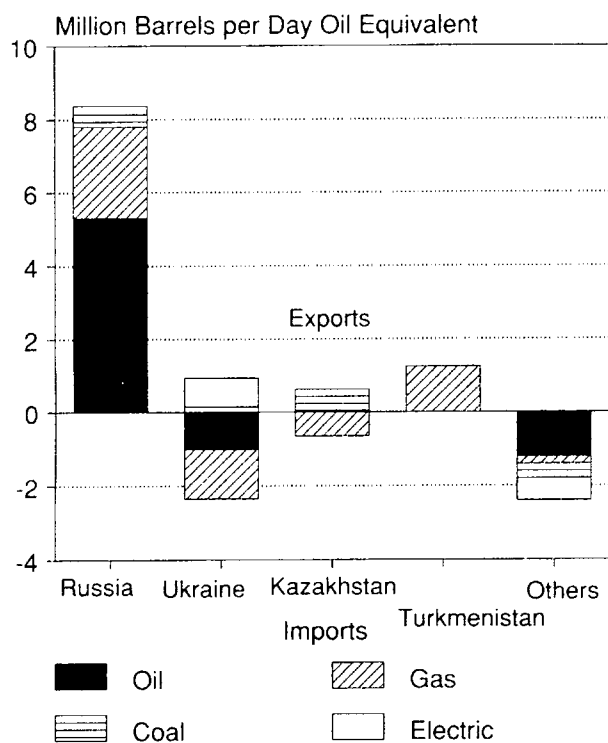


Azimuthal Equidistant  
Polar Projection



year. It is important to note, however, that measurements of national income are problematic and may bias estimates of energy efficiency. Of the former republics, Russia, Kazakhstan, and Ukraine were the largest producers of energy in 1990; only Russia, Kazakshstan, and Turkmenistan were net energy exporters in that year (Figure 18). The other former republics are net importers of energy. In fact, without Russia, the former Soviet Union would be a significant net importer of energy, importing about 2.6 million barrels per day of oil equivalent of energy in 1990.

**Figure 18. Soviet Energy Trade by Republic, 1990**



Source: Matthew J. Sagers, "Review of Soviet Energy Industries in 1990," *Soviet Geography*, April 1991, Silver Spring, MD.

A brief overview of the energy situations in the 15 former Soviet republics is presented below.

### Armenia

Armenia possesses no indigenous fossil fuel resources and is therefore totally dependent on imports for its oil, gas, and coal demand. Armenia's sole nuclear power plant, at Metsamor, was closed in 1989, reducing the former republic's output of electric power by about 40 percent. Most Armenian energy imports come through

neighboring Azerbaijan, with which Armenia has strained relations, thus making Armenia's energy supplies strategically vulnerable. Armenia is not, however, a particularly energy intensive state, as most economic activity involves mining and subtropical agriculture.

### Azerbaijan

Unlike its western neighbor Armenia, Azerbaijan is rich in energy resources, especially crude oil, and is an important supplier of oil industry equipment and machinery. Azerbaijan is one of only four former republics (along with Russia, Kazakhstan and Turkmenistan) that is a net exporter of petroleum. Most (72 percent) of Azerbaijan's oil production of 240,000 barrels per day is offshore, in the Caspian Sea. Onshore, 36 oil and gas fields are being operated by Azneft, the Azerbaijani national oil production association. Azerbaijan also possesses about 800,000 barrels per day of crude oil refining capacity at the refinery center in Baku, supplied by western Siberian crude (via pipeline), Iranian crude (exchanged for refined products), and local production. Refined petroleum products are sent by barge and train to Ukraine and central Russia.

### Baltic States

The newly independent states of Estonia, Latvia, and Lithuania are highly dependent on energy imports from the former Soviet Union. The three states have established the Baltic Energy Council in order to coordinate their mutual operations and to establish a Baltic energy infrastructure.

Estonia is the only political entity in the world where oil shale is the predominant fuel, satisfying half of its primary energy requirements. Most of it is burned in two power plants near Narva, enabling Estonia to generate a surplus of electricity that is exported to Latvia as well as to St. Petersburg and Pskov in Russia. These exports could decrease, however, due to severe environmental problems associated with the mining and burning of oil shale.

Latvia must import almost all of its electricity and fuel, with its major resource the cascade of 3 hydroelectric plants on the Daugava River. Latvia receives over a quarter of its electricity from Estonia; all of its coal from Poland, Ukraine, and Russia; and all of its oil and gas from Belarus and Russia (along with some refined products in Lithuania). Latvia does, however, have an important bargaining chip in future negotiations for Russian energy supplies; the port of Ventspils is a major export point for Russian oil to Western Europe.

Lithuania imports almost all of its primary energy from Russia (coal and gas), Poland (coal), Ukraine (coal), and Belarus (heavy oil). However, Lithuania's oil burning and nuclear power plants generate a surplus of electricity for export. The nuclear reactors at Ignalina are a complicated issue for Lithuania because they are of the same design as Chernobyl's. Lithuania is in a relatively favorable position because it has a refinery large enough to supply all of the Baltics and has the former Soviet oil export port of Klaipeda which, together with the Latvian port of Ventspils, accounted for nearly 40 percent of Soviet oil exports to Western Europe in 1990.

### **Belarus**

Belarus, like the Baltic states which it borders, is highly dependent on other former Soviet republics for its energy needs. Overall, the former republic consumes around 560,000 barrels per day of oil, and possesses around 800,000 barrels per day of crude oil refining capacity at its two refineries in Mozyr' and Polotsk. These refineries receive oil from three sources: Volga-Urals and Western Siberian crude via pipeline, and local production. Refined products are supplied to local markets as well as to markets in Ukraine. Although Belarus is relatively non-intensive in energy consumption as a whole, it is the most intensive of the 15 former republics in its consumption of oil, primarily due to the importance of the oil refining industry in the former republic. Furthermore, Belarus is strategically important as a transit center for oil and gas shipments from Russia to Eastern Europe.

### **Georgia**

Georgia is also dependent upon imports for most of its energy needs. Although the former republic does produce over 1 million short tons of coal per year, it consumes 1.4 million short tons. Georgia also has significant hydroelectric power resources, with production of around 16 terawatt-hours in 1989. The former republic consumes about 130,000 barrels per day of oil, and has a single, 120,000 barrel-per-day capacity refinery, which it uses to satisfy domestic oil product requirements. Georgia produces no natural gas, importing about 208 billion cubic feet annually from Azerbaijan and Russia.

### **Kazakhstan**

Kazakhstan is a major producer of energy, especially coal, but also oil and gas. Significant amounts of coal are found in the Ekibastuz and Karaganda basins in northeastern Kazakhstan, near West Siberia, while large

reserves of oil and natural gas are located in the northwest near the Caspian Sea. Of particular interest is the Tengiz oil field, which was discovered in 1979 and may contain upwards of 20 billion barrels of oil. Development of Tengiz has been impeded by, among other things, Soviet drilling and production equipment which is poorly-suited to handling the highly corrosive sour crudes and abnormally high downhole pressures of Tengiz. Overall, Kazakhstan produces around 500,000 barrels per day of oil and 250 billion cubic feet of natural gas, while consuming around 450,000 barrels per day of oil and 400 billion cubic feet of gas. Kazakhstan is the most energy intensive former republic.

### **Kyrgyzstan**

Kyrgyzstan neither consumes nor produces significant amounts of energy. The former Soviet republic is relatively non-intensive in its energy use.

### **Moldova**

Primarily an agricultural region, Moldova imports nearly all of its energy from Russia and Ukraine. This includes consumption of 100,000 barrels per day of oil, 138 billion cubic feet of natural gas, and 5 million short tons of coal. Moldova is the least energy intensive former Soviet republic.

### **Russia**

By itself, Russia was the world's largest oil producer in 1990, and preliminary indications are that it remained the largest oil producer in 1991. In addition, it contains the world's greatest natural gas reserves, and one of the world's largest reserves of coal. Russian oil production is centered mainly in West Siberia, specifically the Tyumen Oblast. Russian oil exports to Eastern Europe are transported primarily by pipeline through Ukraine, and to Western Europe via tanker through ports in the Black Sea and the Baltics. Russian natural gas production, like oil production, is concentrated in West Siberia, particularly the giant Urengoi field. Vast amounts of natural gas are also believed to lie beneath the Arctic Ocean. In 1990, Russia produced over 10 million barrels per day of oil (91 percent of the total produced in the former Soviet Union), 23 trillion cubic feet of natural gas (79 percent of the Soviet total), and 400 million short tons of coal (56 percent of the Soviet total). In the same year, the country consumed nearly 5 million barrels per day of oil, 17 trillion cubic feet of natural gas, and 400 million short tons of coal. Total Russian crude oil refining capacity is currently about 8 million barrels per day, accounting for around two-

thirds of total Soviet refining capacity. These refineries are, in general, relatively antiquated and technically unsophisticated, with much less reforming and cracking capacity than U.S. refineries.

### ***Tajikistan***

The former republic is mainly agricultural and produces little energy, except for hydroelectric power, which satisfies much of the country's electricity needs. Tajikistan is relatively non-intensive in its energy use, consuming only 50,000 barrels per day of oil, 65 billion cubic feet of gas, and 1 million short tons of coal.

### ***Turkmenistan***

Turkmenistan produces and consumes around 100,000 barrels per day of oil. It also produces 3.1 trillion cubic feet of natural gas, while consuming only 382 billion cubic feet, thus making it a major exporter of natural gas within the former Soviet Union. Most oil output comes from the Chelken district, with a small amount of offshore production in the Caspian Sea. Turkmenistan is the second largest natural gas producing former Soviet republic. Most of this gas production comes from the Kopet Dag Trough, which extends along the border with Iran. Overall, Turkmenistan produces far more energy than it consumes, and has a relatively high energy intensity level. Turkmenistan has one operating refinery, with 240,000 barrels per day of capacity.

### ***Ukraine***

Ukraine plays a critical role in the energy picture of the former Soviet republics. First, Ukraine contains the Donets Basin, which is the largest coal-producing area in the former Soviet Union. Second, Ukraine is a major

center for heavy machinery and industrial equipment, producing around one-third of Soviet steel pipes, and nearly 17 percent of Soviet oil production machinery. Finally, although the country is a net energy importer, it serves a crucial strategic function as the major export route for Russian energy exports (mainly via pipeline) to Eastern and Western Europe. In fact, along with Belarus, Ukraine has a stranglehold on much of Russia's oil and gas exports to Eastern (and to some extent Western) Europe. Ukraine also contains a heavy concentration of nuclear power plants, with 15 of the 43 Soviet nuclear generating units. Overall, Ukraine consumes about 1.1 million barrels per day of oil, 4.2 trillion cubic feet of natural gas, 166 million short tons of coal, and 287 billion kilowatthours of electricity. It produces about 100,000 barrels per day of oil, 1 trillion cubic feet of natural gas, 183 million short tons of coal, and 305 billion kilowatthours of electricity. Ukraine also possesses 1.1 million barrels per day of crude oil refining capacity.

### ***Uzbekistan***

Uzbekistan produces about 56,000 barrels per day of oil, 1.4 trillion cubic feet of natural gas, and about 7 million short tons of coal. It consumes nearly 220,000 barrels per day of oil, 1.5 trillion cubic feet of natural gas, and 6 million short tons of coal. Oil output has been rising steadily since 1980, receiving a boost in 1990 from the addition of a new oil producing area in the Karshi Steppe region. The Amu-Dar'ya district in western Uzbekistan and eastern Turkmenistan is a major gas-bearing region. The two oil refineries in the former republic have a combined capacity of 180,000 barrels per day, and receive crude oil by rail from Western Siberia. Uzbekistan is relatively non-intensive in its use of energy, except for natural gas, which it utilizes very intensively.

**Table 14. Relative Energy Importance of the Republics, 1990**  
(Thousand Barrels per Day Oil Equivalent)

	Production				Consumption			
	Oil	Gas	Coal	Electricity	Oil	Gas	Coal	Electricity
<b>Armenia</b> .....	<b>0</b> (0)	<b>0</b> (0)	<b>0</b> (0)	<b>17</b> (.6)	<b>75</b> (.9)	<b>81</b> (.7)	<b>4</b> (.1)	<b>18</b> (.8)
<b>Azerbaijan</b> .....	<b>244</b> (2.1)	<b>140</b> (1.1)	<b>0</b> (0)	<b>38</b> (1.4)	<b>215</b> (2.6)	<b>270</b> (2.4)	<b>2</b> (0)	<b>33</b> (1.4)
<b>Belarus</b> .....	<b>40</b> (.4)	<b>3</b> (0)	<b>0</b> (0)	<b>63</b> (2.3)	<b>556</b> (6.6)	<b>142</b> (1.3)	<b>27</b> (5)	<b>65</b> (2.7)
<b>Estonia</b> .....	<b>0</b> (0)	<b>0</b> (0)	<b>0</b> (0)	<b>28</b> (1.0)	<b>62</b> (.7)	<b>25</b> (.2)	<b>4</b> (.1)	<b>15</b> (.6)
<b>Georgia</b> .....	<b>4</b> (0)	<b>0</b> (0)	<b>9</b> (0.1)	<b>23</b> (.8)	<b>130</b> (1.6)	<b>92</b> (.8)	<b>11</b> (.2)	<b>26</b> (1.1)
<b>Kazakhstan</b> .....	<b>502</b> (4.4)	<b>110</b> (.9)	<b>1,164</b> (18.7)	<b>141</b> (5.1)	<b>450</b> (5.4)	<b>175</b> (1.6)	<b>583</b> (11.1)	<b>153</b> (6.3)
<b>Kyrgyzstan</b> .....	<b>4</b> (0)	<b>2</b> (0)	<b>35</b> (.5)	<b>21</b> (.8)	<b>57</b> (.7)	<b>28</b> (.3)	<b>32</b> (.6)	<b>13</b> (.5)
<b>Latvia</b> .....	<b>0</b> (0)	<b>0</b> (0)	<b>0</b> (0)	<b>9</b> (.3)	<b>111</b> (1.3)	<b>48</b> (.4)	<b>5</b> (.1)	<b>15</b> (.6)
<b>Lithuania</b> .....	<b>0</b> (0)	<b>0</b> (0)	<b>0</b> (0)	<b>40</b> (1.4)	<b>173</b> (2.1)	<b>86</b> (.8)	<b>10</b> (.2)	<b>24</b> (1.0)
<b>Moldova</b> .....	<b>0</b> (0)	<b>0</b> (0)	<b>0</b> (0)	<b>25</b> (.9)	<b>103</b> (1.2)	<b>60</b> (0.5)	<b>40</b> (.8)	<b>17</b> (.7)
<b>Russia</b> .....	<b>10,328</b> (90.6)	<b>9,956</b> (78.6)	<b>3,503</b> (56.2)	<b>1,744</b> (62.6)	<b>4,982</b> (59.3)	<b>7,417</b> (67.0)	<b>3,155</b> (60.2)	<b>1,518</b> (62.6)
<b>Tajikistan</b> .....	<b>4</b> (0)	<b>3</b> (0)	<b>6</b> (0.1)	<b>29</b> (1.0)	<b>51</b> (.6)	<b>28</b> (.3)	<b>7</b> (.1)	<b>26</b> (1.1)
<b>Turkmenistan</b> .....	<b>112</b> (1.0)	<b>1,365</b> (10.8)	<b>0</b> (0)	<b>24</b> (.9)	<b>104</b> (1.2)	<b>166</b> (1.5)	<b>5</b> (.1)	<b>12</b> (0.5)
<b>Ukraine</b> .....	<b>100</b> (.9)	<b>451</b> (3.6)	<b>1,463</b> (23.5)	<b>492</b> (17.7)	<b>1,111</b> (13.2)	<b>1,804</b> (16.3)	<b>1,316</b> (23.1)	<b>411</b> (17.0)
<b>Uzbekistan</b> .....	<b>56</b> (.5)	<b>634</b> (5.0)	<b>53</b> (.9)	<b>91</b> (3.3)	<b>218</b> (2.6)	<b>655</b> (5.9)	<b>45</b> (.8)	<b>77</b> (3.2)
<b>Total</b> .....	<b>11,394</b> (100)	<b>12,665</b> (100)	<b>6,235</b> (100)	<b>2,784</b> (100)	<b>8,400</b> (100)	<b>11,078</b> (100)	<b>5,245</b> (100)	<b>2,424</b> (100)

Notes: Numbers in parentheses equal percent of former Soviet Union total. Electricity production/consumption estimates include electricity generated by oil, gas, and coal fired power plants.

Sources: Production: Matthew J. Sagers, *Soviet Geography*, April 1991. Consumption: Energy Information Administration, Office of Energy Markets and End Use based upon Energy Information Administration, Analysis Brief: "The Former Soviet Republics" (September 1991) and *International Energy Annual 1990* DOE/EIA-0219(90) (1992).

## References

- American Chemical Society, *Environment, Science and Technology*, Vol. 25, No. 4 (Washington, DC, 1991).
- American Nuclear Society, Inc., *Nuclear News*, selected issues (La Grange Park, IL).
- Baltic Ventures Inc., *Baltic Business Report*, Vol. 1, No. 3 (West Newton, MA, June 1991).
- Butterworth-Heinemann Limited, *Energy Policy* (London, England, October 1991).
- Cambridge Energy Research Associates, "The Future of Soviet Gas: Crisis or Bubble?" (Cambridge, MA, 1991).
- Eastern Bloc Research Ltd., *Eastern Bloc Energy*, selected issues (London, England).
- The Economist Newspaper N.A., *The Economist*, "Energy and the Environment" (London, England, August 31, 1991).
- Edmonds and Reilly, "Global Energy and CO<sub>2</sub> to the Year 2050," *Energy Journal*, Vol. 4, No. 3 (Washington, DC, 1985).
- Energy Information Administration, *Annual Energy Outlook 1992*, DOE/EIA-0383(92) (Washington, DC, January 1992).
- Energy Information Administration, *Annual Prospects for World Coal Trade 1991*, DOE/EIA-0363(91) (Washington, DC, June 1991).
- Energy Information Administration, *Performance Profiles of the Major Energy Producers 1990*, DOE/EIA-0206(90) (Washington, DC, January 1992).
- Energy Information Administration, *International Energy Annual*, DOE/EIA-0219, selected issues (Washington, DC).
- Energy Information Administration, *Supplement to the Annual Energy Outlook 1992*, DOE/EIA-0408(92) (Washington, DC, 1992).
- Energy Market Consultants Ltd., *Monthly Energy Market Review: USSR, Eastern Europe & China*, selected issues (London, England).
- Financial Times Business Information Ltd., *Energy Economist*, selected issues (London, England).
- Financial Times Business Information Ltd., *European Energy Report*, selected issues (London, England).
- International Energy Agency, *Energy Policies of IEA Countries: 1990 Review* (Paris, France, 1991).
- McGraw-Hill, *Nucleonics Week*, selected issues (New York, NY).
- Petroleum Economics Ltd., *Soviet Energy Developments*, selected issues (London, England).
- The Petroleum Finance Company, Ltd., *The Petroleum Quarterly*, selected issues (Washington, DC).
- PlanEcon, Inc., *PlanEcon Energy Report* (Washington, DC, December 1991).
- PlanEcon, Inc., *PlanEcon Report*, selected issues (Washington, DC).
- PlanEcon, Inc., *Eastern European Energy Outlook* (Washington, DC, October 1991).
- PennWell Publishing Co., *Oil and Gas Journal*, selected issues (Tulsa, Oklahoma).
- The Petroleum Economist Ltd., *Petroleum Economist*, selected issues (London, England).
- Petroleum Economics Ltd., *Soviet and East European Energy Developments*, selected issues (London, England).
- Reed Business Publishing Group, *International Water Power and Dam Construction*, selected issues (Surrey, England).
- Sagers, Matthew J., "Review of Soviet Energy Industries in 1990," *Soviet Geography* (Silver Spring, MD, April 1991).
- Salay, Jurgen, "The Energy Sector in the Baltic Republics," a paper presented at the meeting of the IIASA International Energy Workshop (Laxenburg, Austria, June 18, 1991).
- The Scientific American Inc., "Energy for the Soviet Union, Eastern Europe and China," *Scientific American* (New York, NY, September 1990).
- Stephenson, John, "The Potential for Collaboration Between Ontario Hydro and the Baltic Power Sector," a paper presented at the meeting of the IIASA International Energy Workshop (Laxenburg, Austria, June 14, 1991).

## **Appendix A**

# **Analytical Methods**

## Appendix A

# Analytical Methods

This appendix provides brief descriptions of methods used to construct the Index of Oil Vulnerability presented in Figure 3 of this *International Energy Outlook 1992 (IEO92)* and the uncertainty ranges presented in several figures and tables of the *IEO92*. Additional sources of information about this index and the *IEO92* uncertainty ranges are also provided.

### Index of Oil Vulnerability

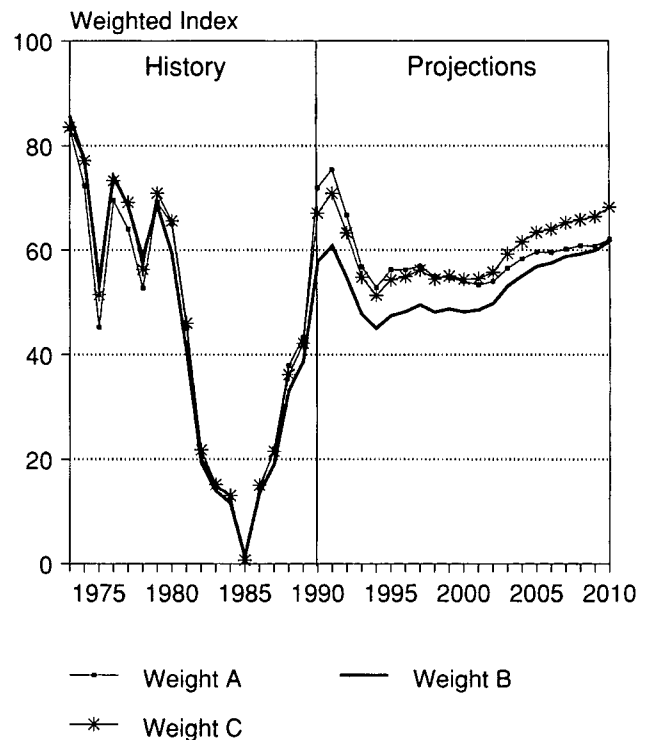
The Index of Oil Vulnerability consists of a weighted average of the normalized values of three variables. These are: the percent of Market Economy consumption coming from the Persian Gulf, the level of excess crude oil production capacity available in any given year, and the level of petroleum stocks in the Market Economies. The normalized values are then weighted to illustrate the index as shown in Figure 3 of the *IEO92*. Since the weights are judgmental, alternate weighting schemes are examined in this Appendix.

Figure A1 shows the results of using alternate weighting schemes. The weights used are as follows:

	Series		
	A	B	C
<b>Excess Capacity</b> . . . . .	70	50	60
<b>Persian Gulf Share</b> . . . . .	15	30	30
<b>Stocks</b> . . . . .	15	20	10

As can be seen in Figure A1, the basic pattern of the index does not vary significantly as different weighting schemes are used because the underlying series tend to move in the same direction over time. The values for Series B are presented in Figure 3 of the *IEO92*.

Figure A1. Vulnerability Index



Sources: **History:** Energy Information Administration, *Annual Energy Review 1990*, DOE/EIA-0384(90), and *International Petroleum Statistics Report*, DOE/EIA-0520(92/01). **Projections:** Derived from Tables 2 and 4 and assumptions about growth in overall petroleum demand and planned additions to strategic stocks.

Relatively lower weights were given to the stock variable. While stocks can be used to offset production losses, historically, this response has very seldom been observed. Detailed information on the data and methods used to construct this index are presented in Energy Information Administration, Energy Demand and Integration Division Memorandum, "Index of Energy Vulnerability," March 5, 1992.

## Uncertainty Ranges

Uncertainty, an inevitable aspect of the projection process, is frequently conveyed by a set of scenarios or cases. Five distinct scenarios are presented in the *Annual Energy Outlook 1992*: Reference, High Economic Growth, Low Economic Growth, High Oil Price, and Low Oil Price. The scenario name indicates the changed assumption made from Reference assumptions, and the scenario values reflect this changed assumption. In the *IEO92*, uncertainty is conveyed by a set of ranges around a base case, rather than by a unique set of scenarios. For example, the high range for total energy consumption for each country or country group and for each projected year is determined by (1) assuming higher rates of economic growth (0.5 percentage points above base-case rates), calculating the resulting differences in consumption from the base-case levels, and squaring these differences; (2) assuming a higher ratio of total energy consumed per dollar of gross domestic product (10 percent higher than base-case ratios), calculating resulting differences from base-case levels, and squaring these differences; (3) adding the squared differences from the first two steps and then taking the square root of that sum; (4) adding the results from step 3 to the base-case amounts. The result is a range value with a difference from base-case consumption that is greater than either of the two differences derived by changing a single assumption but less than the difference had the two changed assumptions been considered simultaneously. The low range for total energy consumption is determined the

same way, using minus 0.5 percentage points and minus 10 percent in the calculations.

The implied assumption underlying this approach is that it is less likely that the extreme of all possible specified events will occur simultaneously than it is that some set of events between the specified base-case and the extreme-case levels will occur. The ranges derived by this approach do not represent confidence intervals or probability levels around the base-case projections. When considered appropriate, the high and low range values for regional totals are also determined using this approach, again under the assumption that individual country experiences will likely vary from the extremes.

To maintain consistency with projections presented in the *Annual Energy Outlook 1992*, range values for the United States are not derived using the approach described above. Rather, they are selected directly from the five scenarios mentioned previously. Determinations of range values for world oil prices and for consumption of specific energy sources also vary somewhat from the example presented here, primarily in terms of the number of assumptions altered. A detailed discussion of the determination of ranges is presented in *World Energy Projection System 1992 Model Documentation Report*, forthcoming. The base-case projections and associated ranges presented here can be replicated using archived personal computer diskettes entitled "World Energy Projection System Spreadsheet, 1992," available from EIA's National Energy Information Center (202/586-8800).



Mommy and  
Daddy Buy Me  
U.S. Savings Bonds  
for When I Go  
to College.



**U.S. SAVINGS BONDS**

THE GREAT AMERICAN INVESTMENT

Now tax free for education. It's smarter than ever to start saving today!

Energy Information Administration  
U.S. Department of Energy  
Forrestal Building, EI-231  
Washington, DC 20585

THIRD-CLASS MAIL  
POSTAGE & FEES PAID  
U. S. DEPT. OF ENERGY  
PERMIT NO. G-765

OFFICIAL BUSINESS  
PENALTY FOR PRIVATE USE, \$300

Address Correction Requested  
Do Not Forward

