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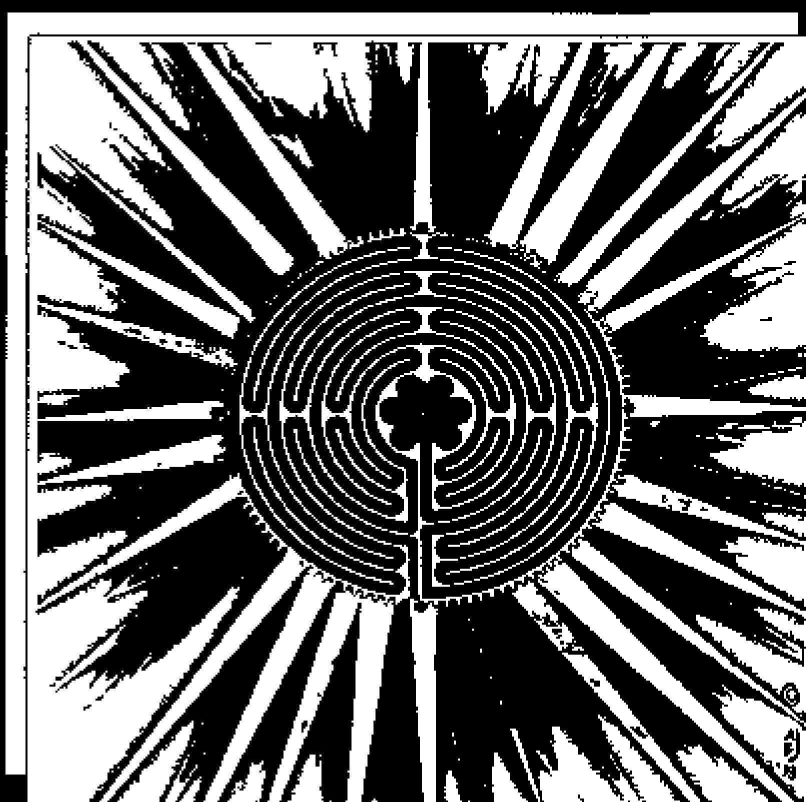
International Energy Outlook 1999



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International Energy Outlook

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

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Preface

This report presents international energy projections through 2020, prepared by the Energy Information Administration. The outlooks for major energy fuels are discussed, along with electricity, transportation, and environmental issues.

The *International Energy Outlook 1999* (*IEO99*) presents an assessment by the Energy Information Administration (EIA) of the outlook for international energy markets through 2020. The report is an extension of EIA's *Annual Energy Outlook 1999* (*AEO99*), which was prepared using the National Energy Modeling System (NEMS). U.S. projections appearing in *IEO99* are consistent with those published in *AEO99*. *IEO99* is provided as a statistical service to energy managers and analysts, both in government and in the private sector. The projections are used by international agencies, Federal and State governments, trade associations, and other planners and decisionmakers. They are published pursuant to the Department of Energy Organization Act of 1977 (Public Law 95-91), Section 205(c). The *IEO99* projections are based on U.S. and foreign government policies in effect on October 1, 1998.

Projections in *IEO99* are displayed according to six basic country groupings (Figure 1). The industrialized region includes projections for nine individual countries—the United States, Canada, Mexico, Japan, France, Germany, Italy, the Netherlands, and the United Kingdom—plus the subgroups Other Europe and Australasia (the latter defined as Australia, New Zealand, and the U.S. Territories). The developing countries are represented by four separate regional subgroups: developing Asia, Africa, Middle East, and Central and South America. China and India are represented in developing Asia; Brazil is represented in Central and South America; and new to this year's report, national-level projections are provided for South Korea (represented in developing Asia) and Turkey (represented in the Middle East). The nations of Eastern Europe and the former Soviet Union are considered as a separate country grouping (EE/FSU).

The report begins with a review of world trends in energy demand. The historical time frame begins with data from 1970 and extends to 1996, providing readers with a 26-year historical view of energy demand. The *IEO99* projections cover a 24-year period.

High economic growth and low economic growth cases were developed to depict a set of alternative growth paths for the energy forecast. The two alternative growth cases consider different levels of future growth in regional gross domestic product (GDP). The resulting projections—and the uncertainty associated with making international energy projections in general—are discussed in the first chapter of the report. The status of environmental issues, including global carbon emissions, is reviewed. Comparisons of the *IEO99* projections with other available international energy forecasts are also included in the first chapter.

The next part of the report is organized by energy source. Regional consumption projections for oil, natural gas, coal, nuclear power, and renewable energy (hydroelectricity, geothermal, wind, solar, and other renewables) are presented in the five fuel chapters, along with a review of the current status of each fuel on a worldwide basis. The third part of the report looks at energy consumption in the end-use sectors, beginning with a chapter on energy use for electricity generation. New to this year's *Outlook* are chapters on energy use in the transportation sector and on environmental issues related to energy consumption.

Appendix A contains summary tables of the *IEO99* reference case projections for world energy consumption, GDP, energy consumption by fuel, electricity consumption, carbon emissions, nuclear generating capacity, energy consumption measured in oil-equivalent units, and regional population growth. The reference case projections of total foreign energy consumption and consumption of natural gas, coal, and renewable energy were prepared using EIA's World Energy Projection System (WEPS) model, as were projections of net electricity consumption and carbon emissions. Reference case projections of foreign oil consumption were prepared using the International Energy Module of the National Energy Modeling System (NEMS). In addition, the NEMS Coal Export Submodule (CES) was used to derive flows in international coal trade, presented in the coal chapter. Nuclear *consumption* projections for the reference case were derived from the International Nuclear Model, PC Version (PC-INM). Nuclear *capacity* projections for the reference case were based on analysts' knowledge of the nuclear programs in different countries.

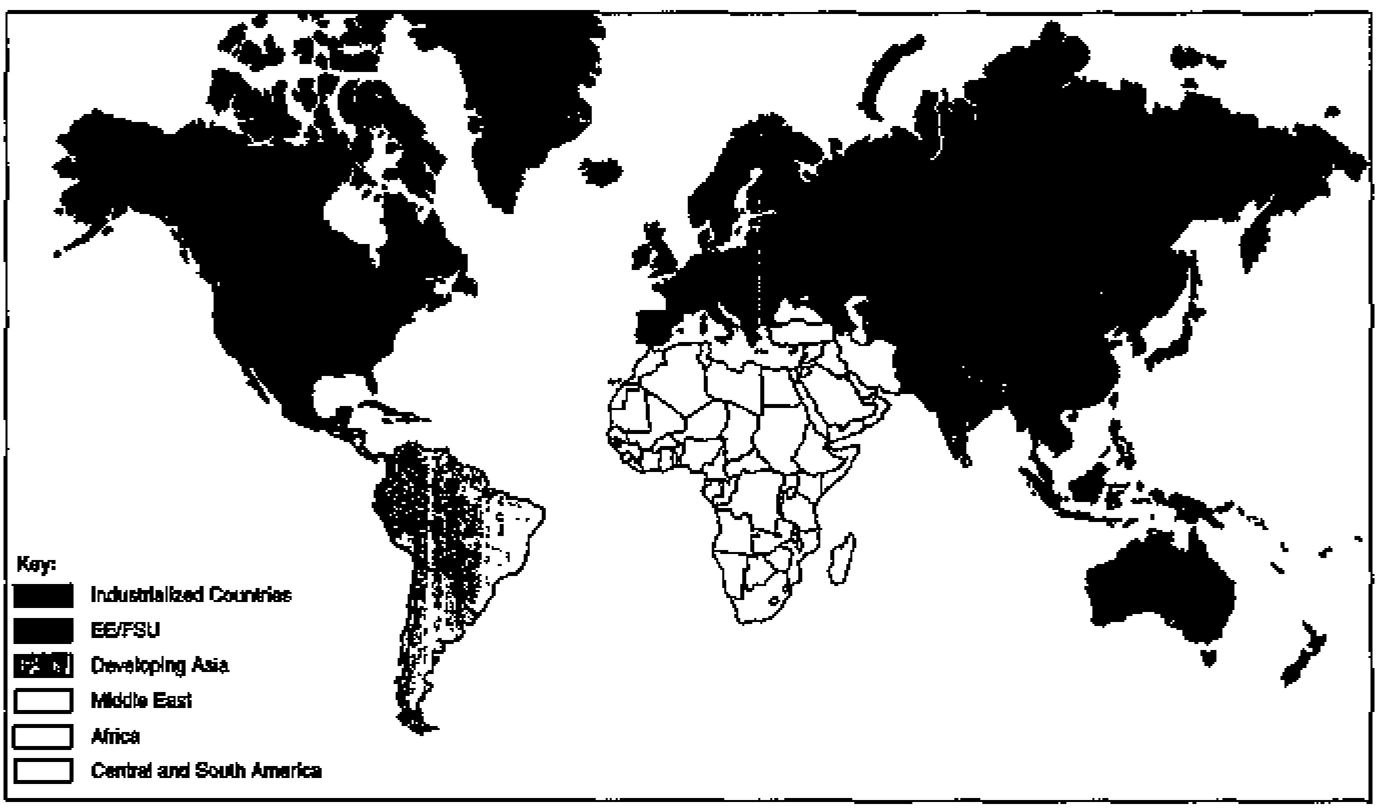
Appendixes B and C present projections for the high and low economic growth cases, respectively. Nuclear *capacity* projections for the high and low growth cases were based on analysts' knowledge of nuclear programs. Nuclear *consumption* projections for both cases were derived from WEPS.

Appendix D contains summary tables of projections for world oil production capacity and oil production in the reference case and four alternative cases: high oil price, low oil price, high non-OPEC supply, and low non-OPEC supply. The projections were derived from WEPS and from the "DESTINY" International Energy Forecast Software. Appendix E presents regional forecasts of transportation energy use in the reference case, derived from the WEPS model. Appendix F describes the WEPS model, and Appendix G presents an evaluation of the performance of past *IEO* forecasts for the years 1990 and 1995.

The six basic country groupings used in this report (Figure 1) are defined as follows:

- **Industrialized Countries** (the industrialized countries contain 17 percent of the 1998 world population): Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and the United States.
- **Eastern Europe and the former Soviet Union (EE/FSU)** (7 percent of the 1998 world population):
  - **Eastern Europe:** Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Hungary, Macedonia, Poland, Romania, Serbia and Montenegro, Slovakia, and Slovenia.
  - **Former Soviet Union (FSU):** The Baltic States of Estonia, Latvia, and Lithuania, as well as Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan.
- **Developing Asia** (54 percent of the 1998 world population): Afghanistan, Bangladesh, Bhutan, Brunei, Cambodia (Kampuchea), China, Fiji, French Polynesia, Hong Kong, India, Indonesia, Kiribatia, Laos, Malaysia, Macau, Maldives, Mongolia, Myanmar (Burma), Nauru, Nepal, New Caledonia, Niue, North Korea, Pakistan, Papua New Guinea, Philippines, Samoa, Singapore, Solomon Islands, South Korea, Sri Lanka, Taiwan, Thailand, Tonga, Tuvalu, Vanuatu, and Vietnam.
- **Middle East** (3 percent of the 1998 world population): Bahrain, Cyprus, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, Turkey, the United Arab Emirates, and Yemen.

Figure 1. Map of the Six Basic Country Groupings



Source: Energy Information Administration, Office of Integrated Analysis and Forecasting.

- **Africa** (12 percent of the 1998 world population): Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo (Brazzaville), Congo (Kinshasa), Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Ivory Coast, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Reunion, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, St. Helena, Sudan, Swaziland, Tanzania, Togo, Tunisia, Uganda, Western Sahara, Zambia, and Zimbabwe.
- **Central and South America** (6 percent of the 1998 world population): Antarctica, Antigua and Barbuda, Argentina, Aruba, Bahama Islands, Barbados, Belize, Bolivia, Brazil, British Virgin Islands, Cayman Islands, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, Falkland Islands, French Guiana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Montserrat, Netherlands Antilles, Nicaragua, Panama Republic, Paraguay, Peru, St. Kitts-Nevis, St. Lucia, St. Vincent/Grenadines, Suriname, Trinidad and Tobago, Uruguay, and Venezuela.

In addition, the following commonly used country groupings are referenced in this report:

- **G-7 Countries:** United States, Japan, Canada, United Kingdom, France, Germany, and Italy.
- **Organization of Petroleum Exporting Countries (OPEC):** Algeria, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, the United Arab Emirates, and Venezuela.
- **Pacific Rim Developing Countries:** Hong Kong, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand.
- **Persian Gulf:** Bahrain, Iran, Iraq, Kuwait, Qatar, Saudi Arabia, and the United Arab Emirates.
- **Organization for Economic Cooperation and Development (OECD):** Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, South Korea, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States.
- **Annex I Countries** (countries participating in the Kyoto Protocol on Greenhouse Gas Emissions): Australia, Austria, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, European Community, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein, Lithuania, Luxembourg, Monaco, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, United Kingdom of Great Britain and Northern Ireland, and the United States.[1]

Objectives of the *IEO99* Projections

The projections in *IEO99* are not statements of what will happen, but what might happen given the specific assumptions and methodologies used. These projections provide an objective, policy-neutral reference case that can be used to analyze international energy markets. As a policy-neutral data and analysis organization, EIA does not propose, advocate, or speculate on future legislative and regulatory changes. The projections are based on current U.S. and foreign government policies. Assuming current policies, even knowing that changes will occur, will naturally result in projections that differ from the final data.

Models are abstractions of energy production and consumption activities, regulatory activities, and producer and consumer behavior. The forecasts are highly dependent on the data, analytical methodologies, model structures, and specific assumptions used in their development. Trends depicted in the analysis are indicative of tendencies in the real world rather than representations of specific real-world outcomes. Even where trends are stable and well understood, the projections are subject to uncertainty. Many events that shape energy markets are random and cannot be anticipated, and assumptions concerning future technology characteristics, demographics, and resource availability cannot be known with any degree of certainty.

[1]Turkey and Belarus are Annex I nations that have not ratified the Framework Convention on Climate Change and did not commit to quantifiable emissions targets under the Kyoto Protocol.

Highlights

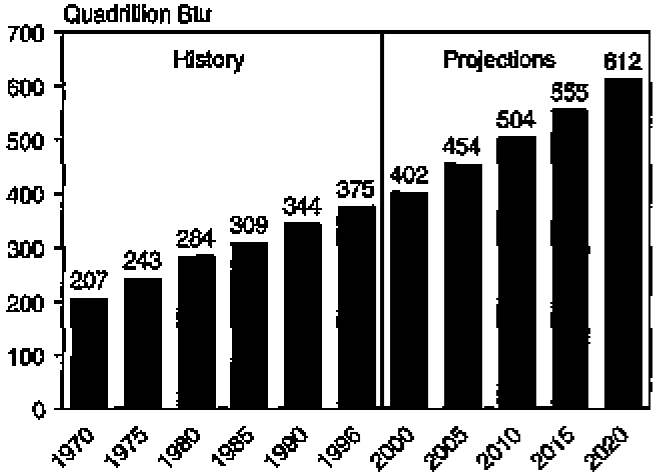
World energy consumption is projected to increase by 65 percent from 1996 to 2020. The current economic problems in Asia and Russia have lowered projections relative to last year's report.

In the reference case projections for this *International Energy Outlook 1999* (*IEO99*), world energy consumption reaches 612 quadrillion British thermal units (Btu) by 2020 (Figure 2 and Table 1)—an increase of 65 percent over the 24-year projection period. The *IEO99* projection for the world's energy demand in 2020 is about 4 percent (almost 30 quadrillion Btu) lower than last year's projection. The downward revision is based on events in two parts of the world: Asia and Russia. In Asia, the economic crisis that began in early 1997 persisted throughout 1998, as economic recession deepened in Japan, the region's largest economy. In Russia, a deteriorating economy was propelled further downward by the August 1998 devaluation of the ruble and the collapse of the Russian banking system.

Growth in energy demand has been severely hampered by the current international economic troubles. The curtailed demand for oil and natural gas resulting from the Asian economic recession and warmer than expected winters in North America and Europe in 1998 resulted in worldwide energy surpluses which have, in turn, helped drive oil prices to 20-year lows. Uncertain financial markets have made it difficult to secure financial backing for some projects. Exploration and development expenditures for oil and gas were sharply cut back in most parts of the world at the end of 1998. Russia's economic troubles have meant that investments that would have been used to expand the country's participation in international oil and natural gas markets have been tabled for the near future.

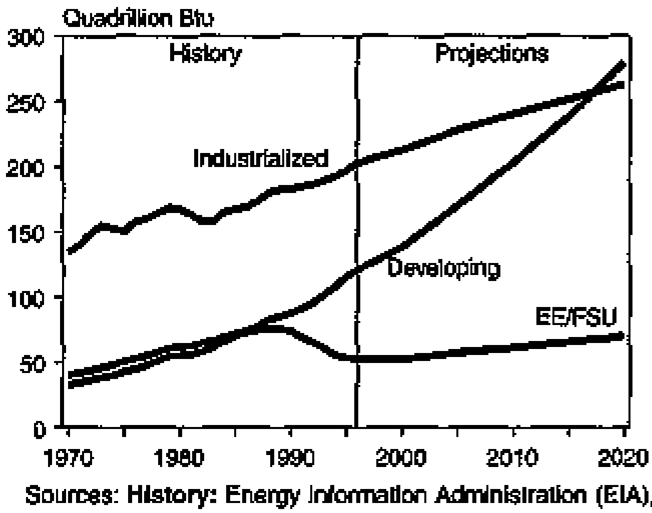
Despite the current economic problems affecting the countries outside the industrialized world, *IEO99* still projects that much of the growth in energy use will occur in those countries over the next two decades. Energy consumption in the developing world (defined as developing Asia, Africa, the Middle East, and Central and South America) is expected to more than double over the projection period, with highest growth rates expected in developing Asia and Central and South America. Indeed, energy use in the developing world is projected to surpass that of the industrialized world by 6 percent in 2020—some 16 quadrillion Btu—whereas in 1996 energy consumption in the developing countries was about 40 percent lower than that in the industrialized countries (Figure 3).

Figure 2. World Energy Consumption, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

Figure 3. World Energy Consumption by Region, 1970-2020



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The projections for Eastern Europe and the former Soviet Union (EE/FSU) have been lowered by about 13 percent relative to last year's outlook, primarily because of the expectation that economic recovery in the FSU

Table 1. Energy Consumption and Carbon Emissions by Region, 1990-2020

Region	Energy Consumption (Quadrillion Btu)				Carbon Emissions (Million Metric Tons)			
	1990	1996	2010	2020	1990	1996	2010	2020
Industrialized	182.7	202.5	240.4	262.8	2,850	2,980	3,535	3,907
EE/FSU	73.6	52.4	61.0	69.8	1,290	842	935	1,024
Developing								
Asia	51.4	74.5	127.6	177.9	1,065	1,474	2,426	3,377
Middle East	13.1	17.3	27.0	34.7	229	283	434	555
Africa.	9.2	11.1	15.5	18.9	178	198	270	325
Central and South America	13.7	17.7	32.6	47.7	174	206	418	629
Total	87.4	120.6	202.8	279.2	1,646	2,161	3,547	4,886
Total World	343.8	375.5	504.2	611.8	5,786	5,983	8,018	9,817

Sources: **History**: Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

will be delayed more than expected. Less than a year ago, most forecasting sources were projecting positive growth for Russia's economy—the largest economy in the FSU—and accelerating recovery in the years to come; but at the end of 1998 it seemed likely that there would be negative economic growth in 1999 with no positive growth expected before 2001. In the *IEO99* reference case, energy use in the FSU is projected to begin recovering by 2005, but even at the end of the projection period consumption remains below its 1990 level (Figure 3).

In the industrialized countries, a major issue for the development of energy markets appears to be the possible impact of the Kyoto Climate Change Protocol, which would require reductions or limits to the growth of carbon emissions within the Annex I countries[2] between 2008 and 2012, resulting in a combined 4-percent reduction in emissions relative to 1990 levels. As of March 15, 1999, 83 countries had signed the Kyoto Protocol; however, none of the Annex I countries had ratified it by the time the *IEO99* was prepared for publication. Should the Kyoto Protocol enter into force, it could have profound effects on the use of energy in the industrialized world.

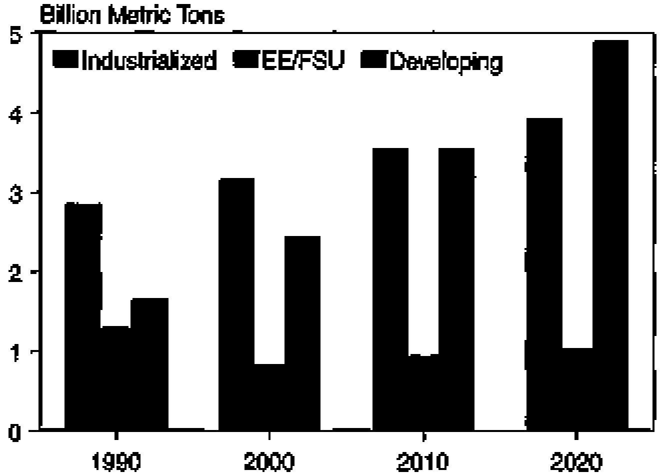
The *IEO99* reference case projection suggests that the industrialized world would account for about 30 percent of the world's increment in energy use between 1996 and 2010. If the Protocol's emissions targets were achieved solely by reducing fossil energy use, consumption of fossil fuels in the industrialized countries would be reduced by between 30 and 60 quadrillion Btu—equivalent to between 15 and 30 million barrels of oil per day. It is more likely, however, that fuel-switching opportunities will be used and that a more modest reduction in total fossil fuel use will be required. Emissions trading and other offsets (such as reforestation) that may be allowed under the Protocol could further lower the need for fossil fuel reductions; however, the specific mechanisms for such offsets have not yet been established.

An offset that could provide an alternative to reducing fossil fuel consumption is the concept of "joint implementation" under the Kyoto Protocol. Joint implementation is a mechanism by which emissions reduction projects could be undertaken by private parties or governments outside their own countries. The Kyoto Protocol proposes two parallel mechanisms to implement the concept of joint implementation: Article 6, under which projects undertaken in an Annex I country could generate emissions reduction units transferrable to another Annex I country; and Article 12, the "clean development mechanism," under which projects undertaken in a non-Annex I country could generate certified emissions reductions transferrable to an Annex I country to meet its emissions target.

World carbon emissions are expected to reach 8.0 billion metric tons by 2010 and 9.8 billion metric tons in 2020 according to the *IEO99* reference case projection (Figure 4), which does not take into account the potential impact of the Kyoto Protocol. In this forecast, world carbon emissions exceed their 1990 levels by 39 percent in 2010 and by 70 percent in 2020. Emissions in the industrialized world grow by about 1.0 billion metric tons between 1990 and 2020, with about half the growth arising from an increase in the use of natural gas as countries continue to choose less carbon-intensive natural gas over the more carbon-intensive coal for electricity generation and industrial uses.

[2]The Annex I countries under the Framework Convention on Climate Change are Australia, Austria, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Lithuania, Luxembourg, the Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russia, Slovakia, Slovenia, Spain, Sweden, Switzerland, the Ukraine, the United Kingdom, and the United States. Turkey and Belarus are also considered Annex I countries, but neither has agreed to any limits on greenhouse gas emissions.

Figure 4. World Carbon Emissions by Region, 1990-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

In the developing countries, carbon emissions are projected to grow more quickly. Emissions from the developing countries were about 60 percent of those from the industrialized countries in 1990, but by 2010 they will surpass them. The rapid increase is expected to be caused both by rapid economic growth, accompanied by growing demand for energy, and by continued heavy reliance on coal—the most carbon-intensive of the fossil fuels—especially in developing Asia.

To achieve the emissions targets proposed under the Kyoto Protocol, emissions in 2010 would have to be 24 percent lower than those currently projected for the industrialized, Annex I countries (Table 2). In the United States and Canada, meeting the targets would require reductions of 30 and 27 percent, respectively, from 2010 projected emissions. In contrast, emissions in the EE/FSU are so much lower now than they were in 1990 that it is doubtful they could be restored to those levels by 2010.

If energy consumption in the countries of the FSU grows as projected in the *IEO99* reference case, carbon emissions will remain about 33 percent below the levels allowed under the Protocol (which requires no reductions from 1990 emissions levels in the transitional economies of the FSU). Even in Eastern Europe, where countries are allowed to increase emissions in 2010 to 7 percent above their 1990 levels, emissions will still be about 18 percent below the required targets. The Kyoto targets for Bulgaria, Hungary, Poland, and Romania—which currently account for some 66 percent of all emissions from Eastern European countries—were recalculated in this year's *IEO* to reflect Article 3.5 of the Protocol, which allows the four countries to use base years other than 1990. Bulgaria and Romania are using 1989 as a base year; Poland is using 1988; and Hungary is using the average emissions for the years 1985 to 1987. As a result, the Kyoto target for total carbon emissions for Eastern Europe in 2010 is 320 million tons in *IEO99*, up from 277 million metric tons in the *International Energy Outlook 1998* (*IEO98*).

Table 2. Projected Effects of the Kyoto Protocol on Carbon Emissions in Annex I Countries, 2010

Region and Country	Carbon Emissions (Million Metric Tons) 1990	2010, *IEO99* Reference Case	2010, Kyoto Protocol Target	Change From *IEO99* Reference Case, 2010 (Million Metric Tons)	Change From 1990 Emissions (Percent)	Change From *IEO99* Reference Case, 2010 (Percent)
Annex I Industrialized Countries						
United States	1,346	1,790	1,252	-538	-7	-30
Canada	126	162	118	-44	-6	-27
Western Europe	936	1,021	862	-160	-8	-16
Japan	274	322	258	-64	-6	-20
Australasia	90	113	97	-16	7	-14
Total Annex I Industrialized	**2,772**	**3,408**	**2,586**	**-822**	**-7**	**-24**
Transitional (EE/FSU)[a]						
Former Soviet Union	991	666	990	324	0	49
Eastern Europe	299	270	320	50	7	18
Total EE/FSU	**1,290**	**935**	**1,309**	**374**	**1**	**40**
Total	**4,062**	**4,344**	**3,895**	**-449**	**-4**	**-10**

[a]Annex I countries in the EE/FSU currently account for 83 of FSU carbon emissions, 94 percent of Eastern Europe's carbon emissions, and 86 percent of the total for the EE/FSU region.

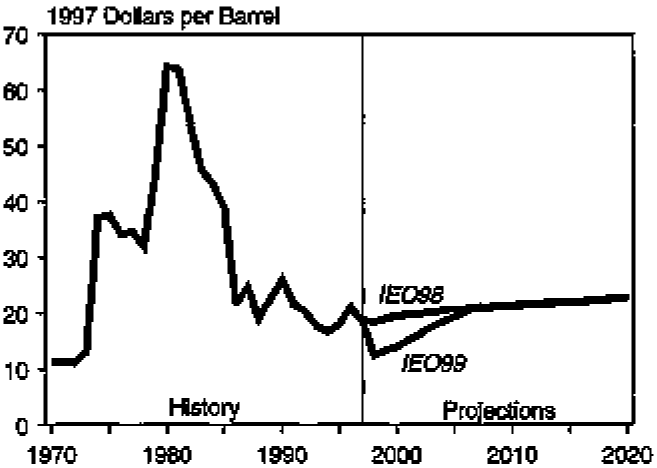
Sources: **1990:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

The reduction in expected energy consumption for the FSU region in this year's projections could substantially change the amount of effort required by the Annex I countries as a whole to meet their Kyoto Protocol targets. In *IEO98*, energy demand in the FSU was expected to recover to its 1990 level by the end of the projection period. Carbon emissions were also expected to rise, but they remained below the 1990 level because the recovery featured increases in the use of less carbon-intensive natural gas rather than more carbon-intensive coal. As a result, *IEO98* projected that in 2010 credits available from the FSU would contribute 199 million metric tons to the total of 822 million metric tons that the industrialized Annex I countries would need to eliminate from the baseline projection to meet the Annex I targets. In this year's projection, however, the potential contribution in 2010 from the FSU has increased by 62 percent, to 324 million metric tons.

The economic collapse in Russia has meant reductions from the *IEO98* projections of FSU fossil fuel use in 2010: 21 percent for oil, 10 percent for natural gas, and 22 percent for coal. *IEO99* projects that, by 2010, the resulting emissions from this lowered outlook for fossil fuel use in the FSU reach only 666 million metric tons, nearly 16 percent less than projected in *IEO98*. Because the transitional Annex I countries currently account for about 86 percent of the EE/FSU region's total emissions, much of the projected emissions reduction could be used as tradable emissions units with the industrialized Annex I countries as they attempt to meet Kyoto Protocol emissions targets. Accordingly, with the higher level of credits available from the EE/FSU, Annex I countries would need to reduce emissions by 10 percent from the reference case projection to meet their Kyoto Protocol targets, rather than by 16 percent as reported in *IEO98*. Indeed, emissions are expected to grow by 7 percent between 1990 and 2010 in the industrialized Annex I countries and the EE/FSU combined, because the 27-percent decrease in emissions expected for the EE/FSU offsets the 23-percent increase projected for the industrialized Annex I countries.

Oil prices fell to historic low levels in 1998, with average crude oil prices one-third lower than in 1997. The *IEO99* reference case price projection traces slow recovery over the next several years, as surplus oil supply is used to meet slower demand growth than was projected in *IEO98*. World oil prices are expected to reach $23 per barrel (constant 1997 U.S. dollars) at the end of the projection period—about the same as in last year's forecast (Figure 5). For the near term, however, the *IEO99* price trajectory is substantially altered by the plummeting oil prices in 1998 that were not anticipated in last year's report. The timing and magnitude of an expected rebound in both oil demand and oil prices are the source of much uncertainty. Nevertheless, short-term price movements generally have not affected long-term price projections 5 to 10 years out.

Figure 5. Comparison of 1998 and 1999 World Oil Price Projections



Sources: History: Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). *IEO98:* EIA, *International Energy Outlook 1998*, DOE/EIA-0484(98) (Washington, DC, April 1998). *IEO99:* EIA, World Energy Projection System (1999).

Despite relatively low prices in the near term, deepwater exploration and development initiatives should continue to be developed at a slower pace, with offshore West Africa emerging as a potential source of major oil production. Technology and resource availability can sustain large increments in oil production capabilities in many parts of the world at prices ranging from $18 to $22 per barrel, but the present low price environment makes it likely that the pace of development in some highly prospective areas—including especially the Caspian Sea region—will be slowed.

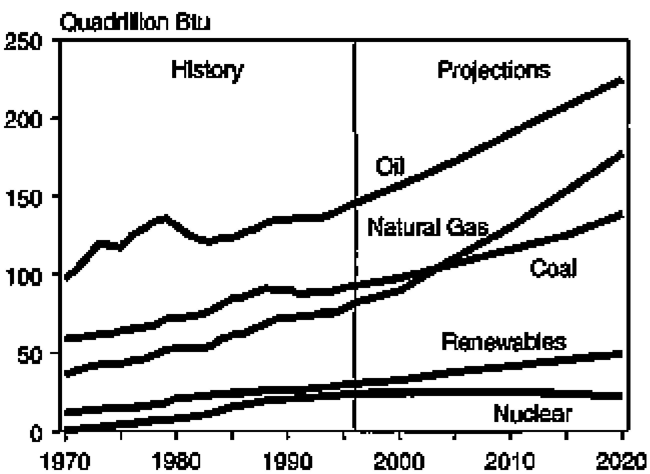
By the middle of 1998, declining world oil prices caused renewed efforts to lower oil production under the sponsorship of the Organization of Petroleum Exporting Countries (OPEC). In both March and June, OPEC and key non-OPEC producers Mexico and Norway agreed to restrict their crude oil sales, and there were indications from several other producers that they would cut back production. Their efforts were not supported by Iraq, which wanted to increase oil sales. As a result, oil production management efforts had only modest success. OPEC's share of world oil supply is projected to increase significantly over the forecast horizon, but competitive forces are expected to remain strong enough to forestall efforts to increase real oil prices substantially.

Oil is projected to remain the world's dominant energy source even as its share of world energy consumption slips somewhat over the next two decades, falling from

40 percent to 38 percent as countries switch to natural gas and other types of fuel, particularly for electricity generation in many industrialized and developing countries. Oil consumption in the reference case is projected to reach 110 million barrels per day by 2020. In the industrialized countries, most of the growth in oil use is projected for the transportation sector, where competition from other fuels is limited. In the developing countries, oil use for transportation increases more rapidly than in the industrialized countries, and substantial growth is also expected for other uses of petroleum fuels. Expanding industrial activity and power generation will be fueled in part with oil, especially in Asia, where natural gas is less available than it is in North America and Europe.

On the whole, natural gas is projected to be the fastest-growing primary energy source from 1996 to 2020. Within the next decade, world natural gas consumption is expected to surpass coal consumption (Figure 6). Gas is becoming the fuel of choice for new electricity generation worldwide, primarily because combined-cycle gas turbine plants tend to be less expensive to build than other means of power generation. And in Central and South America, gas-fired electricity generation capacity is being built to diversify national power supplies that have been based largely on hydropower, which can be unreliable in times of drought. Moreover, among fossil fuels, natural gas is the most likely to be in greater demand in times of favorable supply and demand economics and increasingly stringent environmental regulation. Environmental benefits accrue from increased gas use because of its clean burning characteristics and low carbon content as compared with other fossil fuels.

Figure 6. World Energy Consumption by Fuel Type, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

World coal use is also projected to increase, at an average annual rate of 1.6 percent per year on a short ton basis over the projection period. Strongest growth in demand is projected for the developing world, where coal use more than doubles between 1996 and 2020. The worldwide increase in coal use is attributable mainly to increases in developing Asia—particularly in China and India. Indeed, *IEO99* projects that China and India will account for more than 90 percent of the worldwide increment in coal consumption over the projection horizon.

In the industrialized world coal demand remains nearly flat through 2020, and in the EE/FSU it is expected to decline by almost 30 percent. There have been major declines in EE/FSU coal production and use since the social and political upheaval of the late 1980s and early 1990s. As the region recovers, natural gas is expected to be employed for many of the uses historically ascribed to coal.

Nuclear power supplied 17 percent of the world's electricity generation in 1997, and 10 countries met at least 40 percent of their total electricity demand with electricity from nuclear power plants. Over the next two decades, however, nuclear power declines in the *IEO99* reference case. Only the developing nations and Japan are projected to have net additions to nuclear power capacity. In other regions, countries that are operating older reactors and have other, more economical options for new generating capacity are expected to let their nuclear capacity fade as nuclear units are retired. Market competition from natural gas, public concern about the safety of nuclear reactor operations, and the problems associated with the disposal of nuclear waste are affecting nuclear power programs in many nations. On the other hand, it is possible that ratification of the Kyoto Protocol could change the outlook for nuclear power. Nuclear power under a high capacity scenario could reduce projected world carbon emissions by 6 percent in 2020, or an estimated 206 million metric tons.

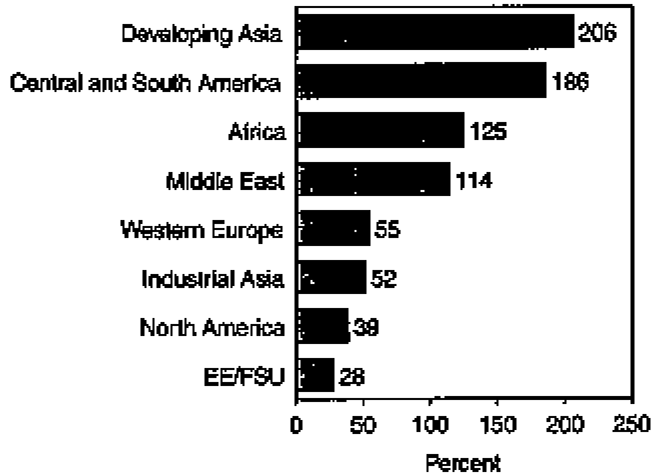
Low fossil fuel prices in world energy markets continue to diminish the potential for rapid development of renewable energy sources worldwide. Again, however, the Kyoto Protocol may provide an opportunity for growth in renewable energy demand. In the *IEO99* reference case, hydroelectricity and other renewable energy sources maintain an 8-percent share of total energy consumption throughout the projection period. Almost half the total growth in the use of renewables is projected for the developing world, where large-scale hydroelectric projects boost the level of renewable consumption. In 1998, China and India pledged increases in large-scale hydroelectric development. In China, hydroelectric projects currently under construction amount to some 32 gigawatts of installed generating capacity, and in India nearly 4 gigawatts of new hydroelectric capacity is planned to be operating by 2002.

World net electricity consumption is expected to increase from 12 trillion kilowatthours in 1996 to 22 trillion kilowatthours in 2020. The economic troubles of Southeast Asia and Russia are expected to slow the growth in electricity demand over the next few years, but electricity demand in the developing countries still is projected to increase by a robust average of 4.4 percent per year, and the strongest long-term growth is projected for the developing countries of Asia, as well as Central and South America (Figure 7). Rapid population growth, along with greater industrialization and more widespread household electrification, will increase electricity use in those regions. In the industrialized countries, annual growth in net electricity consumption is projected to average around 1.6 percent over the next two decades, primarily because of the continuing spread of electricity-using equipment.

A nation's transportation system is generally an excellent indicator of its level of economic development. In many countries personal transportation still means walking or bicycling, and domestic animals are still used to move freight. Over the next two decades, fast-paced growth of transportation infrastructure is expected in the developing world. Developing Asia and Central and South America are expected to account for 52 percent of the increase in the world's motor vehicle population between 1996 and 2020 (Figure 8).

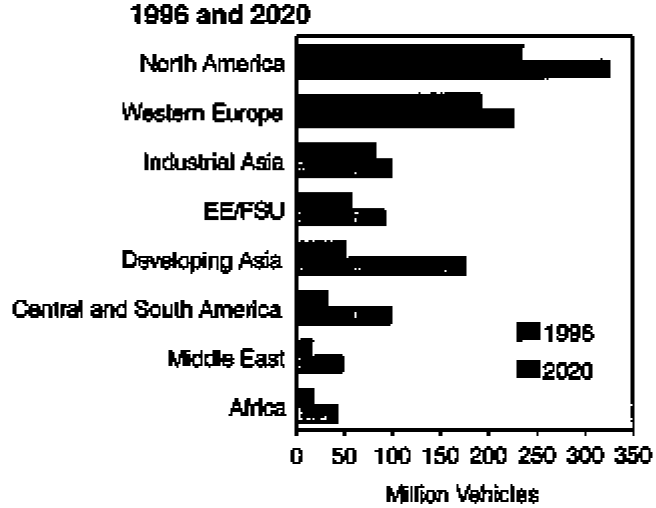
According to the *IEO99* reference case projection, energy use for transportation among the developing countries is projected to grow at an average annual rate of 4.0 percent—nearly triple the rate of growth in the industrialized countries. Growth in the transportation sector in the industrialized countries—where modern transportation systems have been in place for many decades—is expected to average only 1.4 percent per year. Even in the most economically advanced countries, however, transportation energy consumption per capita continues to increase over the projection period, as rising per capita incomes are accompanied by purchases of larger personal vehicles and by increased travel for business and vacations.

Figure 7. Projected Change in Net Electricity Consumption by Region, 1996-2020



Sources: **1996:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **2020:** EIA, World Energy Projection System (1999).

Figure 8. Road Vehicle Populations by Region, 1996 and 2020



Sources: **1996:** American Automobile Manufacturers Association, World Motor Vehicle Data (Detroit, MI, 1997). **2020:** EIA, World Energy Projection System (1999).

World Energy Consumption

The IEO99 projections indicate substantial growth in world energy use, including substantial increases for the developing economies of Asia and South America. Resource availability is not expected to limit the growth of energy markets.

In 1998, expectations for economic growth and energy market performance in many areas of the world were dashed. The Asian economic crisis proved to be deeper and more persistent than originally anticipated, and the threat and reality of spillover effects grew through the year. Oil prices crashed. Russia's economy collapsed. Economic and social problems intensified in energy-exporting countries and in emerging economies of Asia and South America. Deepening recession in Japan made recovery more difficult in Asia and increased the prospects for slower economic growth in Europe and North America. The rate of worldwide economic expansion in 1998 fell by a third relative to that achieved through most of the 1990s.

Growth in energy demand, the hallmark of recent market performance, has been severely constrained by current economic conditions. Shortage has been replaced by surplus in the hardest hit countries. Fear of spillover effects to other regions, as well as recession in Japan and economic collapse in Russia, caused a range of capital-intensive infrastructure development projects involving power generation, pipeline transport, and liquefied natural gas (LNG) supply to be scaled back or put on hold. Uncertain financial markets have made it more difficult to gain financial backing for some projects. Exploration and development expenditures for oil and gas production were in sharp decline in most parts of the world at the close of 1998. Russia's devaluation and apparent default on international debt were choking off investments designed to maintain or expand its role in international oil and gas markets. Given these developments, the near-term prospects for energy markets have become more risky and uncertain; and to the extent that energy investment is affected, so too are intermediate and long-term prospects for energy supply and demand.

In light of these developments, the *International Energy Outlook 1999* (*IEO99*) contains revisions to long-term projections of growth in energy supply and demand trends, relative to those presented in *IEO98*. The revisions are relatively modest, however: a near-term pause in energy demand growth; somewhat (6 percent) lower levels of aggregate demand in the later years of the projection; and lower projected oil prices for the next few years, followed by recovery to last year's baseline by 2007.

The key themes associated with the *IEO98* reference case projections remain: substantial increases in energy demand, based mostly on fossil fuels are in prospect; a major component of growth in world energy demand will be accounted for by developing economies of Asia and South America; natural gas is increasingly the fuel of choice for future electric power generation; oil demand growth is an increasing function of trends in transportation activity; and, over the projection period of about two decades, resource availability does not limit the development of energy markets.

Each issue of the *IEO* underscores important sources of uncertainty that can dramatically change the future course of events affecting trends in the composition, cost, and level of energy use. Economic growth and energy use are closely tied. Thus, assumptions about alternate paths of economic growth can have significant effects on expected energy requirements. The *IEO99* reference case economic projection adopted for this outlook depicts a recovery in Asia's economic growth beginning in 1999. With the exception of Indonesia, countries currently in recession in Asia are assumed to be back to baseline rates of growth within the next 3 to 5 years. Japan, too, is expected to resume positive rates of economic expansion by 2000. China and India are projected to sustain average growth rates in excess of 5 percent between now and 2020.

The events of the past year demonstrate that economic expansion can falter, with severe implications for energy market developments. The reference case economic growth assumptions may not be realized. Accordingly, alternative growth cases are included in the projections. More so than last year, the reference case projection depends on the continued efficacious application of economic policies designed to counter recession and foster structural reforms within national economies. In various countries, economic stress is leading to increased social tensions. Changing political forces could upset policy expectations in a variety of areas, causing reference case expectations not to be realized. Those who are more pessimistic or who have different views of the political and economic uncertainties in particular regions may have less optimistic expectations for economic growth in some of the regions covered in this review. The alternative growth cases presented here may provide useful perspective to assist their analyses.

IEO99 assumes that the reference case projections are the most likely outlook at this point in time. Aggressive policies to counter recession in Asia and to forestall spillover effects in Europe and the western hemisphere were instituted in 1998 by the International Monetary Fund (IMF), the World Bank, and banking institutions in Europe and the Americas. Signs of economic turnaround are now being reported for Korea, Thailand, Malaysia, and the Philippines.

Additional uncertainty arises from the commitments being made by developed countries under the Kyoto Protocol of the Framework Convention on Climate Change. If those commitments are realized, energy demand could actually be reduced over the next decade. Such a development could lower total world energy consumption in 2010 by more than 10 percent relative to the reference case projection presented here, equivalent to 60 quadrillion Btu or 30 million barrels of oil per day. The Protocol identifies stringent targets for reduced greenhouse gas emissions in developed countries; however, neither policies nor technologies to achieve the targets have been identified for implementation, nor have the countries ratified the agreement. Thus, the Kyoto Protocol is viewed in this report as a factor heightening uncertainties and the need for collateral analysis of the *IEO99* reference case rather than one that *per se* alters it.

Another key source of uncertainty for the long-term evolution of energy markets relates to trends in energy intensities—i.e., the manner in which energy requirements evolve relative to growing income levels. History shows different trends in energy intensity for the developed and developing countries. In developed countries, energy requirements have grown slowly relative to increasing levels of economic activity. That historical trend is projected to continue in the reference case, with energy use rising at only about half the rate of economic expansion.

In the developing countries, energy and economic growth have tended to move in parallel. The process of economic development is energy intensive, and rising living standards enable broad access to electricity and motorized means of transportation. The accompanying widespread development of infrastructure causes growth in energy-intensive industries such as steel and cement. As economies continue to develop, however, the rate of energy use tends to fall relative to economic expansion. Consumer demands tend to evolve toward increased use of services that are not energy intensive.

The reference case projection presented here assumes a declining rate of energy intensity for developing countries over the projection period: by 2020, the relationship between energy and economic growth in developing countries is projected to be is similar to that in developed countries. This is a key assumption. Although per capita energy consumption is expected to rise over the next two decades, the projected levels in 2020 are still low relative to those currently prevailing in developed countries. If energy growth rates do not decline substantially relative to projected economic growth rates, the demand for energy in the developing world, where more than two-thirds of the world's population resides, would be substantially higher.

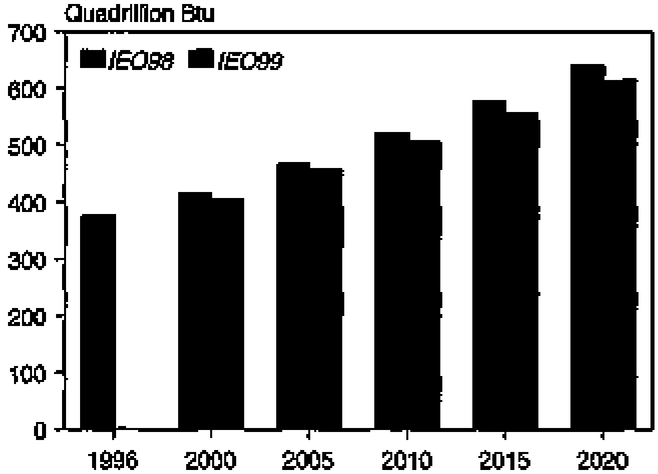
Other key assumptions underlying the *IEO99* reference case projection involve the continuing evolution of world oil markets. Current oil prices are near record low levels. Although some analysts now argue that low oil prices could persist for many years, the reference case assumes a price recovery path that begins in 1999 and returns to the levels projected in the *IEO98* reference case by about 2007. Expectations for long-term recovery in demand growth and only a modest constriction on oil supply, especially in mature producing areas, encourage this view. In addition, *IEO99* assumes no change in the influence of the Organization of Petroleum Exporting Countries (OPEC) on oil markets. It is also assumed that technology and government policies worldwide will support a large expansion in oil supply production capabilities.

Outlook for World Energy Consumption

The prospects for world energy consumption in *IEO99* are somewhat lowered from last year's report. Indeed, in this year's projection, world energy consumption reaches 612 quadrillion British thermal units (Btu) in 2020, almost 30 quadrillion Btu less than last year's forecast (Figure 9). The downward revision flows from events in two parts of the world: the Asian economic crisis—which began in the spring of 1997 and persisted throughout 1998, aided and abetted by the worsening economic situation in Japan—and the prolonged collapse of the Russian economy.

The persistent recession in Japan—the world's second largest economy—has not shown signs of abating. In October 1998, the Japanese Parliament passed a $517 billion package to bail out the country's national banking system and attempt to revive the economy [1]. The Japanese government has estimated that the economy will still shrink by 1.8 percent in the fiscal year ending March 31, 1999 [2]. While the Asian economic crisis does not appear to have dramatically affected China's economy thus far, there are fears that the crisis could threaten its program of economic reform, which is designed to downsize state-owned enterprises in favor of more market oriented activities serving both domestic and export demands [3, p. 274].

Figure 9. Projected World Energy Consumption in *IEO98* and *IEO99*, 2000-2020



Sources: **1996:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1998 and 1999).

Other Southeast Asian economies hit by the recession in mid-1997 began to fare better toward the end of 1998. Interest rates in the second half of 1998 fell sharply in South Korea and more modestly in Thailand, two countries that were hit particularly hard by the economic crisis. Both have adhered to the financial reforms prescribed by the IMF, and it appears that they might begin to see positive economic growth by the end of 1999 [4]. Some growth in exports is now evident, and an inflow of new foreign investment has begun. In contrast, the outlook for Indonesia is much less optimistic. By one estimate, the Indonesian economy was expected to contract by more than 13 percent in 1998, with no positive growth expected before 2000 [4, p. 4].

The deteriorating Russian economy—the largest economy in the former Soviet Union (FSU)—has led to some substantial downward revisions to the *IEO99* projections. The lower expectations for energy growth are caused by the August 1998 devaluation of the Russian ruble, the defaults on public and private debt, the collapse of the Russian banking system, the worsening political situation for Boris Yeltsin and any potential successor, and expected changes in monetary policy that raise the possibility of hyperinflation. Less than one year ago, most forecasting sources were projecting positive growth in Russia's GDP in 1998 and accelerating recovery in the years to follow. In October, PlanEcon revised its GDP forecast for Russia for 1999 from a positive 4.2 percent to a negative 5 percent, with no positive GDP growth expected before 2001 [5, 6].

For the FSU region as a whole, *IEO99* projects that GDP will fall by an average of 2 percent per year between 1996 and 2000, with positive growth returning to the region between 2000 and 2005, averaging about 3 percent per year. As growth resumes, energy consumption in the FSU region is expected to recover. Between 1996 and 2020, energy consumption growth is expected to average 1.0 percent per year. The projection for 2020 is about 10 quadrillion Btu lower than in *IEO98*—equivalent to about 5 million barrels of oil per day.

Despite the downward revisions for expected energy demand worldwide, the *IEO99* reference case projects that energy consumption in 2020 will increase by 236 quadrillion Btu—or about 65 percent—relative to the 1996 level. More than half the increment is expected in the developing countries, where strong economic growth in the long term is expected to increase the demand for energy over the projection period.

The predominant issue for the development of energy markets in the industrialized countries appears to be the potential impact of the Kyoto Protocol. As of March 15, 1999, 83 countries—including the United States—had signed the Kyoto Protocol, which calls for "Annex I" countries[3] to reduce or limit the growth of their carbon emissions between 2008 and 2012. The Protocol remains open for signature until March 15, 1999, but it will come into force only when 55 Parties to the Framework Convention, including Annex I countries that accounted for at least 55 percent of the total carbon dioxide emissions from that group in 1990, have "deposited their instruments of ratification, acceptance, approval or accession" [7]. As of March 15, 1999, only seven countries (Antigua and Barbuda, El Salvador, Fiji, Maldives, Panama, Trinidad and Tobago, and Tuvalu—all non-Annex I countries) had ratified the Protocol.

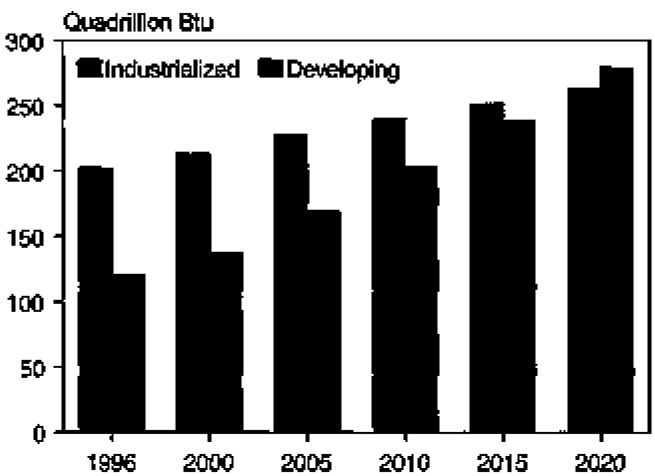
None of the Annex I countries had ratified the Kyoto Protocol by the time this report was prepared for publication. As a result, although the Protocol has the potential to change energy use dramatically in the industrialized world, no adjustments have been made to try to account for the impact of the Protocol. Nonetheless, the Protocol could retard the industrial world's energy demand growth. The *IEO99* reference case projections suggest that industrialized countries can expect to account for about 30 percent of the world's increment in energy use between 1996 and 2010. Were emissions targets identified in the Protocol to be achieved by reducing fossil energy usage, energy consumption overall would be reduced by between 30 and 60 quadrillion Btu—equivalent to between 15 and 30 million barrels of

[3] Australia, Austria, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Lithuania, Luxembourg, the Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russia, Slovakia, Slovenia, Spain, Sweden, Switzerland, the Ukraine, the United Kingdom, and the United States. Turkey and Belarus are also considered Annex I countries, but neither has agreed to any limits on greenhouse gas emissions.

oil per day. On the other hand, with potential fuel-switching opportunities, emissions trading, and other offsets (such as reforestation) allowed under the Protocol, a more modest reduction in fossil fuel use is more likely.

The strongest growth in energy consumption is expected to occur outside the industrialized world, which currently consumes about 40 percent more energy than is consumed by the developing world (Figure 10). By the end of the projection period, energy use in the developing countries (defined as developing Asia, Africa, the Middle East, and Central and South America) is expected to exceed that in the industrialized world. Such large increments in energy use in the developing world would have a dramatic effect on world energy markets. The *IEO99* projections assume substantial financial investment in all phases of energy production, distribution, and transmission. If the assumed levels of investment are to be achieved, world government policies must continue to evolve to favor private-sector incentives for trade and development.

Figure 10. Projected Energy Consumption in the Industrialized and Developing Regions, 2000-2020

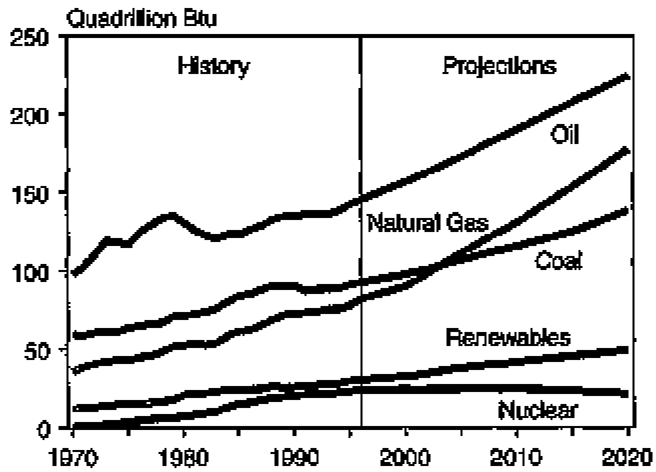


Sources: **1996:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

Outlook by Energy Source

The *IEO99* reference case, based on "business as usual" assumptions, projects that every energy source except nuclear power will grow over the 1996 to 2020 forecast period (Figure 11), although renewable energy sources are not expected to grow as fast over the next 24 years as they have in the past. Worldwide, oil remains the dominant source of energy throughout the projection horizon, as it has since 1970. Oil's key role in the transportation sector—where it does not currently have any serious competition from other energy sources—helps to sustain its position among fuel sources. Oil use in the electric power sector is projected to decline in relative terms, but the fast-paced growth of personal transportation, especially in the developing world, will absorb any losses in the electricity sector.

Figure 11. World Energy Consumption by Fuel Type, 1970-2020

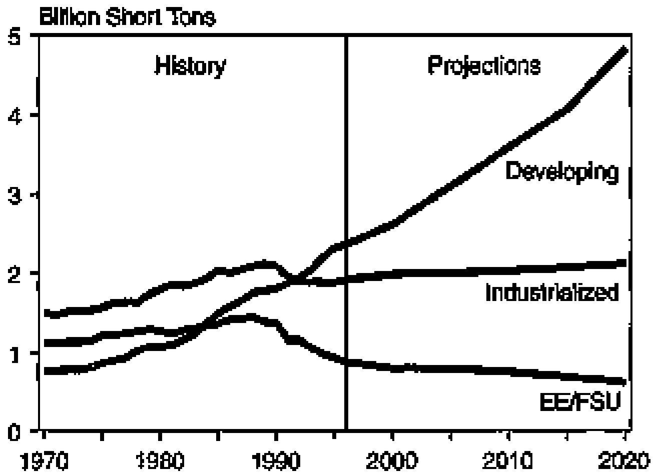


Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database, and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

Natural gas is expected to be the fastest-growing primary energy source from 1996 to 2020. Worldwide consumption of natural gas increases by 3.3 percent per year (on a Btu basis) over the 24-year projection period, nearly twice as fast as oil (1.8 percent per year) and coal (1.7 percent per year). Gas is increasingly the fuel of choice for new electric power generation, primarily because combined-cycle gas turbine plants tend to be less expensive to build and are more efficient than other means of power generation. It is also a fuel of choice for environmental reasons. Local air pollution can be lessened by shifting from coal to natural-gas-fired generation. On a Btu basis, carbon emissions from natural gas combustion are less than half those for coal. Within the next decade, natural gas use is expected to exceed coal consumption, with the margin growing ever larger in subsequent years.

Coal use worldwide is projected to increase by 2.4 billion short tons, from 5.2 to 7.6 billion short tons, between 1996 and 2020. Strongest growth in demand is projected for the developing world, where coal use increases by 3.0 percent per year over the projection period (Figure 12). The worldwide increase in coal use is attributable mainly to increases in developing Asia—particularly, China and India. Indeed, *IEO99* projects that China and India alone will account for more than 90 percent of the worldwide increment in coal consumption between 1996 and 2020. In the industrialized world, coal demand remains relatively flat through 2020, with average annual growth of 0.4 percent. Further, in Eastern Europe and the FSU (EE/FSU), coal consumption is projected to decline by 1.5 percent per year. There have been major declines in coal production and use in the EE/FSU since the social and political upheaval of the late 1980s and early 1990s. As the economies of the region recover, natural gas is expected to be used in place of those uses historically ascribed to coal.

Figure 12. World Coal Consumption by Region, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database, and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

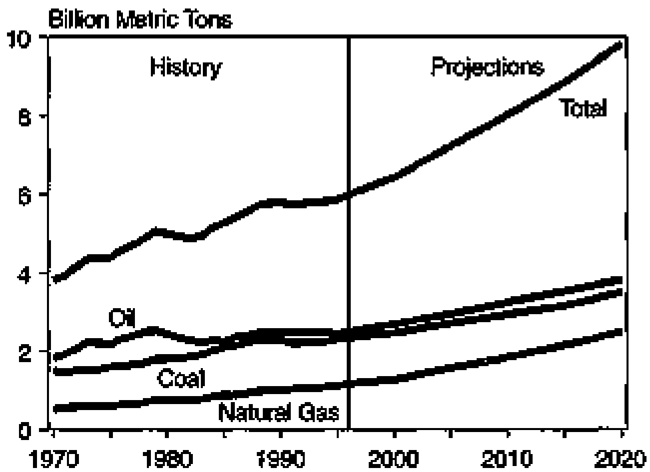
Nuclear power is the only primary energy source projected to decline over the forecast period. After peaking at 2,390 billion kilowatthours worldwide in 2010, nuclear energy use is projected to decline to 2,068 billion kilowatthours in 2020. The worldwide decline is attributed to retirements of nuclear facilities in the industrialized world and in the FSU, where countries are operating older reactors and have other, more economical options for new generating capacity. In the developing world—especially developing Asia—increases in nuclear power generation still are planned in China, India, and South Korea. In addition, it is possible that ratification of the Kyoto Protocol could modify the outlook for nuclear power in the Annex I countries, where the operating lives of nuclear facilities could potentially be extended to constrain greenhouse gas emissions.

Hydroelectricity and other renewable resources maintain an 8-percent share of total energy consumption throughout the projection period. The growth of renewable resources is expected to be restrained somewhat by low fossil fuel prices, which discourage the development of renewable energy sources. As with nuclear power, ratification of the Kyoto Protocol could help renewable energy gain market share if the signatory countries used non-carbon-emitting energy sources to reduce their reliance on fossil fuels and consequently, reduce their greenhouse gas emissions. In Western Europe there is increasing activity in renewable installations, involving particularly wind-generated electricity. The German government announced in December 1998 that Germany's renewable energy use expanded by 30 percent between 1996 and 1997, to 5 billion kilowatthours [8]; however, this still represents only about 1 percent of the nation's total electricity consumption.

Outlook for Carbon Emissions

If energy consumption grows to levels projected in the *IEO99* reference case, annual carbon emissions will reach 8.0 billion metric tons in 2010 and 9.8 billion metric tons in 2020 (Figure 13). Thus, world carbon emissions would exceed 1990 levels by almost 39 percent in 2010 and by 70 percent in 2020. Emissions are projected to rise by 2.2 billion metric tons between 1990 and 2010 and by another 1.8 billion metric tons between 2010 and 2020. Between 1990 and 2020, emissions from the combustion of coal are expected to account for 1.2 billion metric tons of the total increase in worldwide emissions, natural gas 1.5 billion metric tons, and oil 1.3 billion metric tons.

Figure 13. World Carbon Emissions by Fuel Type, 1970-2020

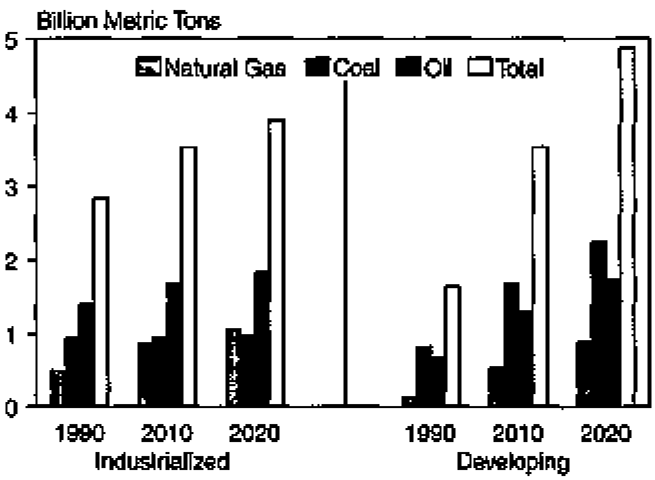


Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database, and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

The Kyoto Protocol, if ratified and implemented, may well influence carbon emissions levels in the future. Only 2 of the 67 countries that had signed the Kyoto Protocol as of December 1998, Fiji and Tuvalu, have actually ratified it, and neither is required to reduce emissions levels under the treaty. As a result, *IEO99* reference case projections have not been adjusted to account for changes that might occur under the Protocol. A discussion of how Kyoto-type scenarios might be achieved through fuel switching, reductions in fossil fuel consumption, and various emissions trading strategies is presented in the final chapter of this report, "Environmental Issues and World Energy Use."

In the industrialized world, carbon emissions are projected to increase from 2.9 to 3.9 billion metric tons between 1990 and 2020, an increment of just over 1.0 billion metric tons (Figure 14). Emissions are expected to grow less than primary energy use mainly because of strong growth in the use of less carbon-intensive natural gas relative to coal, which is more carbon-intensive. About 52 percent of the total increase in emissions in the industrialized countries is attributed to an increase in the use of natural gas. Indeed, by the end of the projection period, emissions resulting from natural gas consumption exceed those from coal for these countries, reflecting the strong growth expected for natural gas relative to coal. Oil remains the dominant source of carbon emissions in the industrialized countries throughout the projection period, because of its role in transportation.

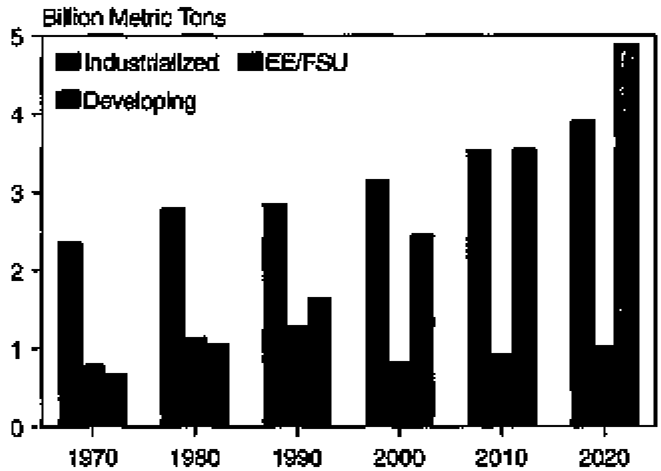
Figure 14. World Carbon Emissions in the Industrialized and Developing Regions by Fuel Type, 1990, 2010, and 2020



Sources: **1990:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

Carbon emissions grow most quickly in the developing countries. By 2010 their emissions are expected to surpass those of the industrialized countries, whereas in 1990 developed countries' emissions were nearly two times those of the countries of the developing world (Figure 15). By 2020, emissions in the developing countries are projected to exceed those of the industrialized countries by nearly 1 billion metric tons (in the context of a world total of 9.8 billion metric tons). The fast-paced growth of emissions in the developing world is attributed to high rates of economic and energy growth, as well as expectations for continued heavy dependence on fossil fuels (particularly coal, the most carbon-intensive of the fossil fuels) especially in developing Asia. Coal use is expected to contribute about 44 percent of the 3.2 billion metric tons of emissions added in the developing countries between 1990 and 2020.

Figure 15. World Carbon Emissions by Region, 1970-2020



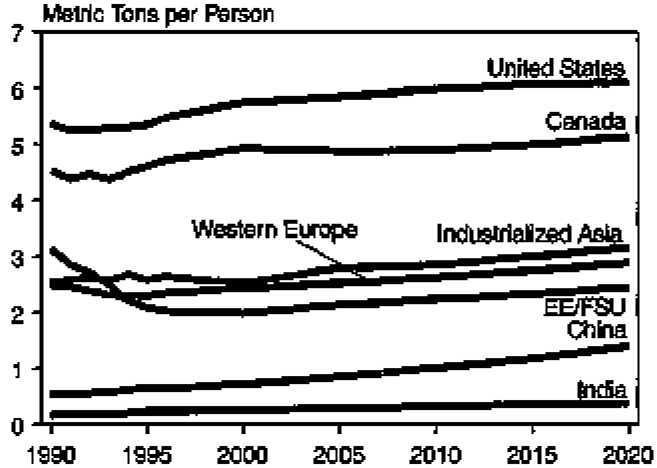
Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database, and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

In the EE/FSU region, carbon emissions remain below their 1990 levels throughout the projection period—a result of the economic and political upheaval in the region during the early 1990s. By 2010, emissions in the EE/FSU are expected to be about 27 percent lower than in 1990. Although some recovery in energy demand is projected by the end of the forecast period, emissions still are expected to reach only 1.0 billion metric tons by 2020, still about 21 percent lower than in 1990. The region is expected to be able to take advantage of its lower emissions levels if a worldwide carbon trading system is developed in the future. Industrialized Annex I countries may seek to buy emissions rights to meet their obligations under the Kyoto Protocol. Procedures for such a system have yet to be established among the participating countries, but negotiations in the matter continue.

Worldwide, carbon emissions per person increase from about 1.1 metric tons per person in 1990 to 1.2 metric tons per person in 2010 and 1.3 metric tons per person in 2020. Per capita emissions in the industrialized countries remain much higher than those of the rest of the world throughout the projection period, increasing from 3.2 to 3.8 metric tons per person between 1990 and 2020 in the *IEO99* reference case. Even in 2020, with a doubling of per capita emissions, the developing world's per capita emissions (0.8 metric tons per person) remain little more than one-fifth the level of the industrialized world. With four-fifths of the world's projected population attributed to the developing countries in 2020, however, relatively small increments in per capita emissions would have a much greater impact on overall emissions than would larger increments in per capita emissions for the industrialized world.

Within the industrialized countries, the United States and Canada have the highest per capita emissions levels throughout the projection period—reaching 6.1 and 5.1 metric tons per person, respectively, in 2020 (Figure 16)—although the growth rate of per capita emissions in both countries is expected to remain fairly flat after 2000. In contrast, per capita emissions in developing countries such as China and India are projected to more than triple between 1990 and 2020, reflecting fast-paced industrialization based largely on fossil fuel consumption.

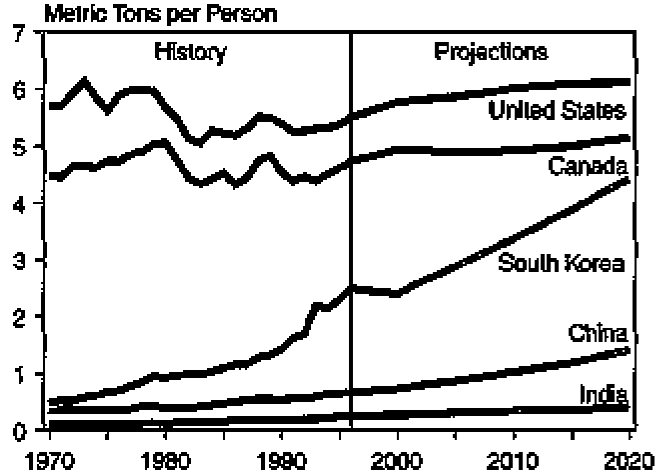
Figure 16. Carbon Emissions per Capita for Selected Regions and Countries, 1990-2020



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

The pace of increase in carbon emissions per capita is even faster in the newly industrialized countries of Southeast Asia. In South Korea, for instance, per capita carbon emissions grew by 6.5 percent annually between 1970 and 1996, reaching 2.5 metric tons per person in 1996 (Figure 17). By 2020, per capita emissions in South Korea are projected to grow to 4.4 metric tons per person, matching the levels in Australasia and substantially exceeding those in Japan (2.9 metric tons per person). Oil remains by far the most widely used energy fuel in South Korea, maintaining a 63-percent share of total energy consumption over the next two decades. Were per capita emissions in China and India to grow over the projection period at the same rate as in South Korea over the past 26 years, total worldwide emissions could exceed current projections by 3.4 billion metric tons, assuming a continuation of current fuel use patterns.

Figure 17. Carbon Emissions per Capita for Selected Countries, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database, and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

Alternative Growth Cases

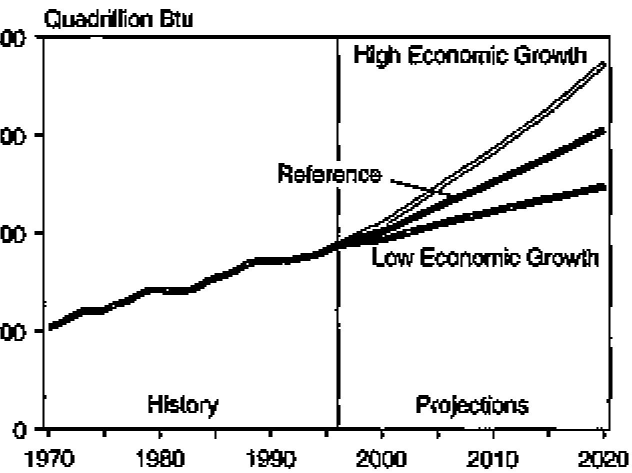
IEO99 includes a high economic growth case and a low economic growth case in addition to the reference case. The reference case projections were derived by establishing a set of regional assumptions about economic growth paths and energy elasticity (the relationship between changes in energy consumption and changes in GDP). The two alternative growth cases, based on alternative ideas about the possible paths of economic growth, were formulated to provide users with a way to quantify the range of uncertainty associated with the reference case.

For the high and low economic growth cases, different assumptions were made about the range of possible economic growth rates in developing and industrialized nations, reflecting the greater uncertainty inherent in attempts to forecast economic growth in developing economies. The same pattern of change in energy intensity relative to GDP (discussed below) was assumed for the high and low growth cases as in the reference case. For industrialized countries, increments of +1.0 and -1.0 percentage points, respectively, were added to the reference case growth rates to generate high and low growth cases. For nonindustrialized countries and regions (apart from China and the EE/FSU), increments of +1.5 and -1.5 percentage points were used to generate the high and low growth cases.

China and the EE/FSU are special cases with regard to prospects for future economic growth. China has experienced high economic growth in the past several years, and the EE/FSU region has suffered a severe economic downturn. In both regions, there is opportunity for substantial change in growth: China has the potential for a larger decline in growth rate given its currently high rate, and there are prospects for a substantial increase in the rate of growth for the EE/FSU nations should their current political and institutional problems be moderated enough for the recovery of a considerable industrial base. Reflecting these uncertainties, -3.0 percentage points were added to China's growth rate for the low economic growth case and +1.5 for the high case; and +3.0 percentage points were added to the EE/FSU growth rate for the high economic growth case and -1.5 for the low case.

In the *IEO99* reference case, total world energy consumption is expected to reach 612 quadrillion Btu in 2020, with the industrialized countries consuming 263 quadrillion Btu and the rest of the world 349 quadrillion Btu. Under the assumptions of the high economic growth case, total world energy consumption would be 747 quadrillion Btu in 2020, 136 quadrillion Btu higher than in the reference case (Figure 18). In the low economic growth case, worldwide energy consumption in 2020 would be 497 quadrillion Btu, 115 quadrillion Btu less than in the reference case. Clearly, there is a substantial range between the low and high economic growth cases. The range between the cases for total world energy consumption—251 quadrillion Btu—is more than 40 percent of the total reference case consumption projected for 2020.

Figure 18. World Energy Consumption in Three Cases, 1970-2020



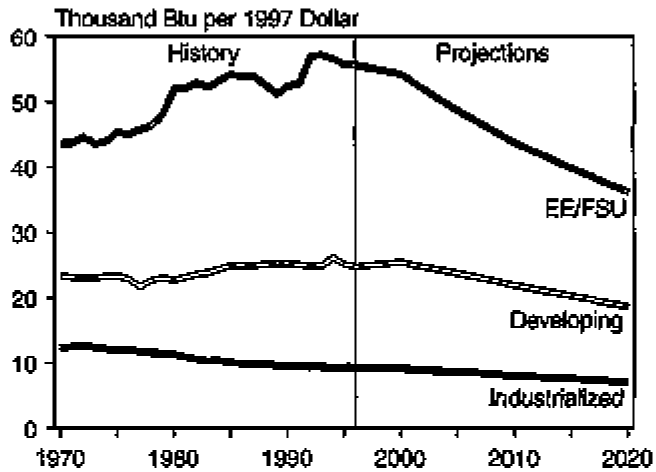
Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database, and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

Trends in Energy Intensity

Another way to look at uncertainty in long-term energy demand developments is in terms of the way energy demand evolves relative to GDP over time. Economic growth and energy demand are linked, but the strength of that link varies among regions and stages of economic development. In industrialized countries, history shows the link to be relatively weak. That is, energy demand growth lags behind economic growth. For every percent increase in economic activity, energy demand increases only about half a percent. In developing countries, demand and economic growth have tended to be more closely correlated, with energy demand growth tending to track the rate of economic expansion.

The historical behavior of energy intensity in the FSU is problematic. The EE/FSU economies have always maintained higher levels of energy intensity than either the industrialized or developing nations (Figure 19). In the FSU, however, energy consumption grew more slowly than GDP until 1990, when the collapse of the Soviet Union created a situation in which both income and energy use were declining, but GDP fell more rapidly. As a result, energy intensity began to rise.

Figure 19. World Energy Intensity by Region, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database, and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

The stage of economic development and the standard of living of individuals in each region strongly influence the link between economic growth and energy demand. Advanced economies with high living standards tend to have relatively high energy use per capita, but they also tend to be economies where per capita energy use is relatively stable or changes occur very slowly. Here increases in energy use tend to correlate with employment and population growth. There is a high penetration rate of modern appliances and motorized transportation equipment in the industrialized countries. As a result, increments to personal income tend to result in spending on goods and services that are not energy intensive. To the extent that spending is directed toward energy-consuming goods, it involves more often than not purchases of new equipment to replace old capital stock. The new stock is often more efficient than the equipment it replaces, resulting in a weaker link between income and energy demand. In developing countries, standards of living, while rising, tend to be low relative to those in more advanced economies. As a result, many energy-using devices are being widely used for the first time, causing energy use to track more closely with rising income levels.

Indeed, changing growth patterns of energy intensity could have dramatic impacts on energy consumption in the projection period, particularly among the developing countries. For instance, if energy intensities are assumed to decrease (improve) in the developing countries according to a percentage that represents the single greatest annual improvement observed between 1990 and 1996, energy consumption in the developing world would be 174 quadrillion Btu in 2020—about 100 quadrillion Btu less than the reference case projection of 279 quadrillion Btu. On the other hand, if energy intensities in the developing world are assumed to increase (worsen) by the highest annual rate of the 6-year period, energy consumption in the developing countries climbs to 926 quadrillion Btu in 2020—more than three times the reference case projection.

Forecast Comparisons

Another way to illustrate the uncertainty associated with the projections presented in the *IEO99* is to compare them with those derived by other forecasters. Four organizations provide forecasts comparable to those in *IEO99*. The International Energy Agency (IEA) provides "business as usual" projections to the year 2020 in its *World Energy Outlook 1998*. Standard & Poor's DRI (DRI) also provides energy consumption forecasts to 2020 in its *World Energy Service: World Outlook 1998*. Petroleum Economics, Ltd. (PEL) and Petroleum Industry Research Associates (PIRA) publish energy forecasts for the world, but only to the years 2015 and 2010, respectively.

All the forecasts for total world energy consumption are similar (Table 3). Both IEA and DRI project growth of 2.0 percent per year between 1995 and 2020, and *IEO99* projects 2.1-percent annual growth. The PEL and PIRA growth rate projections are similar, but their projection horizons are not the same as those for the other forecasts. The PEL projections are for 1995 to 2015, and the PIRA projections are for 1995 to 2010. For those periods, the *IEO99* reference case projects 2.1-percent annual growth from 1995 to 2015 (compared with PEL's projection of 2.0 percent) and 2.2-percent annual growth from 1995 to 2010 (the same as the PIRA projection).

In the projections that extend through 2020, almost all the projected growth rates for the industrialized region fall within the range defined by the *IEO99* low and high economic growth cases. One notable exception is the IEA projection for North America. IEA expects energy use in North America to increase by only 0.7 percent per year between 1995 and 2020, whereas the *IEO99* reference case projects growth of 1.3 percent per year. The IEA suggests that the differences between its projections for North America and the *IEO99* projections may be attributed, in part, to its expectations of higher oil and natural gas prices [3, pp. 222-223].

Comparing projections from the PIRA series with those from *IEO99* over the 1995-2010 period, North America is the only industrialized region for which there are substantial differences between *IEO99* and an alternative series. PIRA expects energy use in North America to grow by 1.2 percent per year between 1995 and 2010, whereas the *IEO99* reference case projects 1.5-percent annual growth. In the *IEO99* low economic growth case, North America's energy consumption increased by 1.2 percent per year, exactly the same as the rate in the PIRA series. Comparing *IEO99* and PEL over the 1995-2015 period, the PEL growth rates for all industrialized regions fall within the range defined by the *IEO99* low and high cases.

The FSU region provides severe challenges for those developing long-term projections. Only one other forecast, by PEL, provided projections for the FSU separated from the Eastern European countries. Over the 1995-2015 period, *IEO99* frames a wide range for projected growth in energy use in the region, ranging from 0.1 percent per year in the low economic growth case to 2.1 percent per year in the high economic growth case (the 1995-2020 time frame presented in Table 3 provides a range between 0.2 percent per year in the low growth case and 2.4 percent per year in the high growth case). Nevertheless, PEL projects even worse performance than in the *IEO99* low growth case, with no expected growth between 1995 and 2015. For the entire EE/FSU region, all the forecasts have energy consumption growth rates that fall into the range defined by the *IEO99* low and high economic growth cases, including comparisons of PEL and *IEO99* cases over the 1995-2015 period and of PIRA and *IEO99* over the 1995-2010 period.

As might be expected given the continuing regional economic recession, Asia is also a region where the

Table 3. Comparison of Energy Consumption Growth Rates by Region
(Average Annual Percent Growth)

Region	1995-2020						1995-2015	1995-2010
	IEO99							
	Low Growth	Reference	High Growth	*IEO98*	IEA	DRI[a]	PEL	PIRA[a]
Industrialized Countries	0.8	1.2	1.6	1.2	1.0	1.2	1.0	1.1
North America	0.9	1.3	1.6	1.2	0.7	1.2	1.1	1.2
Western Europe	0.7	1.1	1.5	1.2	1.3	1.2	0.9	1.1
Pacific	0.5	1.0	1.6	1.3	1.0	1.2	0.8	0.7
EE/FSU	0.5	1.1	2.4	1.7	1.7	1.2	0.4	0.6
Former Soviet Union	0.2	0.9	2.2	1.6	–	–	0.0	–
Eastern Europe	1.1	1.7	2.6	1.8	–	–	1.5	–
Developing Countries	2.2	3.6	4.7	3.8	3.4	3.1	3.8	4.1
Asia	2.2	3.7	4.7	4.2	3.7	3.2	4.1	3.9
China	2.2	4.1	5.0	4.5	3.5	3.5	4.2	4.4
Other Asia[b]	2.2	3.3	4.3	3.8	4.0	3.0	4.1	4.4
Middle East	1.9	3.0	4.2	2.5	2.6	3.2	3.2	3.4
Africa	1.3	2.3	3.2	2.5	2.6	2.5	2.6	3.3
Central and South America	2.7	4.3	5.8	3.8	2.9	3.1	3.6	3.6
Total World	1.2	2.1	2.9	2.3	2.0	2.0	2.0	2.2

[a]Industrialized Pacific region includes only Japan.
[b]Other Asia includes India and South Korea.
Sources: ***IEO99***: Energy Information Administration (EIA), World Energy Projection System (1999). ***IEO98***: EIA, *International Energy Outlook 1998*, DOE/EIA-0484(98) (Washington, DC, April 1998), Table A1, p. 133. **IEA**: International Energy Agency, *World Energy Outlook 1998* (Paris, France, November 1998), Business As Usual Case, pp. 412-463. **DRI**: Standard & Poor's DRI, *World Energy Service: World Outlook* (Lexington, MA, January 1998), p. 5. **PEL**: Petroleum Economics, Ltd., *Oil and Energy Outlook to 2015* (London, United Kingdom, December 1998), Table 1(i). **PIRA**: PIRA Energy Group, *Retainer Client Seminar* (New York, NY, October 1998), Tables II-4, II-6, and II-7.

expectations for energy demand vary considerably. In the *IEO99* reference case and in the IEA 'business as usual' case, energy demand in developing Asia is expected to increase by 3.7 percent per year between 1995 and 2020. DRI projects a lower growth rate of 3.2 percent per year. PIRA projects a growth in energy use of 3.9 percent per year between 1995 and 2010 (the *IEO99* reference case projects the same growth rate over the same time period), and PEL projects a growth rate of 4.1 percent per year between 1995 and 2015 (*IEO99* is somewhat lower at 3.8 percent per year over the same period). Other Asia includes countries hardest hit by the economic troubles that began in 1997 and continued throughout 1998, such as Thailand, Indonesia, Malaysia, and South Korea. It is clear that there is still much debate among analysts about the time frame needed for these countries to regain momentum for economic expansion and increased demand for energy.

Within Asia, there is more variation in expectations for "other Asia" than for China. *IEO99* and DRI tend to be more conservative than the other forecasts. Between 1995 and 2020, *IEO99* and DRI project energy demand growth in other Asia of 3.3 percent and 3.0 percent per year, respectively. IEA projects 4.0-percent annual growth in other Asian energy use. Between 1995 and 2015, PEL expects energy use in other Asia to increase by 4.1 percent per year, compared with 3.4 percent per year for the same period in the *IEO99* reference case. Between 1995 and 2010, PIRA projects robust average annual growth of 4.4 percent, compared with 3.6 percent in the *IEO99* reference case.

Of the remaining developing regions, the greatest variation in expected growth is seen for Central and South America. *IEO99* is more optimistic about growth in energy use in the region than are any of the other forecast series, projecting growth of 4.3 percent per year over the 1995-2020 period, compared with 3.1 percent per year (DRI) and 2.9 percent per year (IEA). Over the 1995-2010 period, *IEO99* is substantially higher than PIRA in terms of energy demand growth (4.5 and 3.6 percent per year, respectively); and over the 1995-2015 period, *IEO99* projects a substantially higher growth rate (4.4 percent per year) than does PEL (3.6 percent per year).

A key reason for the differences among the various forecasts is that they are based on different expectations about future economic growth rates (Table 4). Expectations for economic growth are substantially alike among

Table 4. Comparison of Economic Growth Rates by Region
(Average Annual Percent Growth)

Region	1995-2020						1997-2010[a]	1995-2010
	IEO99							
	Low Growth	Reference	High Growth	*IEO98*	IEA	DRI	PEL[b,c]	PIRA[b]
Industrialized Countries	1.3	2.3	3.2	2.3	–	2.3	–	2.4
North America	1.4	2.4	3.3	2.1	2.1	2.4	2.7	2.6
Western Europe	1.4	2.4	3.4	2.4	2.0	2.4	2.5	2.5
Pacific	0.9	1.9	2.9	2.3	1.8	1.9	1.7	1.4
EE/FSU	1.4	2.9	5.7	3.7	3.3	3.5	–	3.3
Former Soviet Union	0.5	2.0	4.8	3.6	–	3.1	1.4	–
Eastern Europe	2.7	4.1	7.0	4.4	–	4.1	3.2	–
Developing Countries	3.1	4.8	6.3	5.2	–	4.8	–	4.7
Asia	3.3	5.3	6.8	6.2	–	5.3	–	5.1
China	3.8	6.7	8.1	7.9	5.5	6.7	7.8	6.1
Other Asia[d]	3.1	4.6	6.0	5.2	4.2-4.5	4.6	4.3	3.9
Middle East	2.6	4.1	5.5	3.8	2.7	4.1	3.6	3.6
Africa	2.1	3.6	5.0	4.1	2.5	3.6	2.6	3.5
Central and South America	2.9	4.3	5.7	4.3	3.3	4.3	3.3	3.7
Total World	1.7	2.9	4.0	3.1	3.1	2.9	2.9	3.5

[a]PEL growth rates are for the period 1997-2010, except for Africa, which is 1998-2005.
[b]Industrialized Pacific region includes only Japan.
[c]North America includes only the United States.
[d]Other Asia includes India and South Korea.

Sources: ***IEO99***: Energy Information Administration (EIA), World Energy Projection System (1999). ***IEO98***: EIA, *International Energy Outlook 1998*, DOE/EIA-0484(98) (Washington, DC, April 1998), Table A1, p. 133. **IEA**: International Energy Agency, *World Energy Outlook 1998* (Paris, France, November 1998), Business As Usual Case, p. 30. **DRI**: Standard & Poor's DRI, *World Economic Outlook, Fourth Quarter* (Lexington, MA, November 1998), pp. A5-A6 and B5-B6. **PEL**: Petroleum Economics, Ltd., *Oil and Energy Outlook to 2015* (London, United Kingdom, December 1998). **PIRA**: PIRA Energy Group, *Retainer Client Seminar* (New York, NY, October 1998), Tables II-1 and II-2.

estimates for the industrialized regions from most of the forecasts. The IEA economic growth rates for North America, Western Europe, and the Pacific are lower than the corresponding *IEO99* growth rate projections. The PIRA and PEL forecasts have substantially the same economic growth rates as *IEO99* for the comparable time frames.

Projected GDP growth rates over the 1995-2020 period vary somewhat for the EE/FSU region, as might be expected given the economic straits in which the FSU, and specifically Russia, finds itself. While *IEO99* assumes annual GDP growth of 2.9 percent for the region, IEA projects a more optimistic 3.3 percent per year. The projections in last year's *IEO* were more optimistic at 3.7 percent. Over the 1995-2010 period, PEL and *IEO99* are in relative agreement on the expectations for economic growth in the FSU. PEL projects GDP growth averaging 1.4 percent per year and *IEO99* 1.3 percent per year. The PEL projection for Eastern European countries is more pessimistic than *IEO99*. PEL projects growth of 3.2 percent per year between 1995 and 2010. Over that same time period, *IEO99* projects Eastern European GDP growth at 4.5 percent.

Projections vary not only with respect to the levels of energy demand and economic growth but also with respect to the composition of energy input use (Table 5). *IEO99* expects continued strong growth in world natural gas consumption, growing by 3.3 percent annually between 1995 and 2020. This growth rate, which is the same as the *IEO98* projection, is the most optimistic of all the forecasts. Growth rates for natural gas use among the alternative projections range from 2.3 percent per year (PEL) to 2.9 percent per year (PIRA).

In *IEO99*, projections for all energy sources except natural gas and nuclear power were revised downward from last year's report—a result of increased pessimism for recovery of the economies of the FSU and a downward revision based on the impact of the Southeast Asian economic crisis. The decline projected in *IEO98* for world nuclear consumption was revised upward slightly, so that nuclear energy is now projected to decline by 0.3 percent per year between 1995 and 2020 rather than 0.4 percent per year.

Given the relatively high growth rate of expected gas use, *IEO99* tends to have lower growth rates than the

Table 5. Comparison of World Energy Consumption Growth Rates by Fuel
(Average Annual Percent Growth)

Fuel	1995-2020						1995-2015	1995-2010
	IEO99							
	Low Growth	Reference	High Growth	*IEO98*	IEA	DRI	PEL	PIRA
Oil	1.0	1.8	2.6	2.1	1.9	2.0	1.9	2.0
Natural Gas	2.5	3.3	4.2	3.3	2.6	2.7	2.3	2.9
Coal	0.6	1.7	2.5	2.2	2.1	2.1	2.2	2.2
Nuclear	-0.8	-0.3	0.3	-0.4	0.0	0.7[a]	0.5	0.5
Renewable/Other	1.2	2.0	2.8	2.1	2.5	–	2.0	2.1
Total	1.2	2.1	2.9	2.3	2.0	2.0	2.0	2.2

[a]DRI reports nuclear and hydroelectric power together as "primary electricity."

Sources: *IEO99*: Energy Information Administration (EIA), World Energy Projection System (1999). *IEO98*: EIA, *International Energy Outlook 1998*, DOE/EIA-0484(98) (Washington, DC, April 1998), Table A1, p. 133. IEA: International Energy Agency, *World Energy Outlook 1998* (Paris, France, November 1998), Business As Usual Case, pp. 412-463. DRI: Standard & Poor's DRI, *World Energy Service: World Outlook* (Lexington, MA, January 1998), p. 6. PEL: Petroleum Economics, Ltd., *Long Term Oil and Energy Outlook to 2015* (London, United Kingdom, February 1998). PIRA: PIRA Energy Group, *Retainer Client Seminar* (New York, NY, October 1998), Tables II-8, II-9, and II-10.

alternative forecasters for the remaining fossil fuels. In *IEO99*, oil use grows by 1.8 percent per year worldwide between 1995 and 2020, whereas the range of average annual growth rates among the other forecasters runs from 1.9 percent (IEA) to 2.0 percent (DRI). Coal use in *IEO99* grows by 1.7 percent per year, but the DRI and IEA forecasts project increases of 2.1 percent per year. For both oil and coal, the alternative forecasts fall within the range of projections defined by the *IEO99* low and high economic growth cases.

At first glance, it appears that the *IEO99* projections of growth in the use of non-fossil fuels (i.e., nuclear power and hydroelectricity and other renewables) also are lower than those in the other forecasts. However, DRI produces a forecast only for combined nuclear and hydroelectricity—as "primary electricity." When the *IEO99* projections for the two non-fossil energy sources are combined, they fall in the middle of the range of growth rates expected between 1995 and 2020 by the other forecasters, from 0.7 percent per year (DRI) to 1.2 percent per year (*IEO99*).

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4. WEFA Energy, *Asia Special Report* (Eddystone, PA, November 25, 1998).
5. PlanEcon, *Review and Outlook for the Former Soviet Republics* (Washington, DC, March 1998), p. vi.
6. PlanEcon, *Review and Outlook for the Former Soviet Republics* (Washington, DC, October 1998), p. vii.
7. United Nations Framework Convention on Climate Change, "List of Signatories to the Kyoto Protocol," web site www.unfcc.de (December 3, 1998).
8. NewsEdge Corporation, "Alternative Energy Expands 30 Percent," NewsPage web site www.newspage.com (December 8, 1998).

World Oil Markets

A moderate view of future oil market developments is reflected in IEO99. Sustained high levels of oil prices are not expected, whereas continued expansion of the oil resource base is anticipated.

The crude oil market was wracked with turbulence during 1998, as prices fell by one-third on average from 1997 levels. Even without adjusting for inflation, the world oil price in 1998 was the lowest since 1973. The declining oil prices were influenced by an unexpected slowdown in the growth of energy demand worldwide—less than any year since 1990—and by increases in oil supply, particularly in 1997. Although the increase in world oil production in 1998 was smaller than in any year since 1993, efforts to bolster prices by imposing further limits on production were unsuccessful.

Oil consumption in 1998 was lower than anticipated largely because the recession in Southeast Asia proved to be more severe than expected early in the year. Significant reductions in gross domestic product (GDP) were experienced in Korea, Thailand, and Malaysia. Depression and political turmoil struck Indonesia. Japan, the region's largest economy, moved from slow or no economic growth to decline. Although the Chinese economy continued to grow, it was hampered by a reduction in trade with neighboring countries. As a consequence, a decade-long string of annual increases in oil demand was broken, and Asian oil requirements fell by about 100,000 barrels per day in absolute terms [1] and by more than 1 million barrels per day relative to expectations [2]. Production geared to the earlier expectations created a supply glut, which was exacerbated by a mild winter and lower weather-related demand as well as Iraq's return as a crude oil exporter.

By mid-1998, declining prices set in motion renewed efforts to manage oil supplies under sponsorship of the Organization of Petroleum Exporting Countries (OPEC). Agreements were sought to restrict production within OPEC, and initiatives were launched to gain cooperation from non-OPEC producers. In both March and June, OPEC (excluding Iraq) and key non-OPEC producers Mexico and Norway announced plans to cut oil production. In the remaining months of 1998, however, announced and realized production cuts were not clearly synchronized, and production management efforts had at best only modest success.

By the end of 1998, other constraints on oil supply became increasingly evident. Stripper production in the United States was in decline. Exploration and development spending was being slashed. Rig utilization rates, especially for onshore equipment, had fallen by 30 percent. Announced spending plans worldwide were reduced. Oil-producing countries faced severe fiscal deficits, causing national oil companies to cut capital spending. Private-sector restructuring entered a new stage as mergers involving leading multinational oil companies were announced or consummated. A prime objective of the mergers was to rationalize corporate operations, reducing employment needs and eliminating investment activities with low profit prospects.

How should these developments be factored into the construction of an intermediate- and long-term oil market outlook? One perspective might feature an expectation of continued low oil prices in 1999 and beyond, sustained in part by expectations that economic recovery in Asia will be slow in coming, increasing adverse economic pressures in the rest of the world and causing oil demand to remain flat or decline. This perspective could be further sustained by a view that oil supply development continues even in the context of low oil prices because of technology being applied to highly prospective frontier areas, or because resource-rich OPEC producers—including especially Saudi Arabia—are opening up their countries to high levels of exploration and development activity.

While the risk that such a scenario might transpire is perhaps greater now than a year ago, it is not this report's reference case. Oil prices in the *International Energy Outlook 1999* (*IEO99*) reference case are expected to recover over the next several years as oil demand growth resumes in Asia and is sustained over the next two decades at high levels in developing countries throughout the world. By 2005, oil prices are projected to be in the range of the reference case track presented last year in the *International Energy Outlook 1998* (*IEO98*). Oil demand is expected to reach 110 million barrels per day by 2020, requiring an increment to world production capability of 30 to 40 million barrels per day relative to current capacity. OPEC producers are expected to be the major beneficiaries of increased production requirements, but non-OPEC supply is expected to remain highly competitive—with major increments to supply coming from deepwater resources, especially in West Africa.

Some argue that recent and projected trends in growth for oil production are not sustainable and that within a decade or so we could face severe oil price escalation (see box on page 22). Over the past 25 years, oil prices have been highly volatile. In the future one can expect volatile behavior to recur principally because of unforeseen political and economic circumstances. It is well recognized that tensions in the Middle East, for example, could give rise to serious disruptions in normal oil production and trading patterns. On the other hand, significant excursions from the reference price trajectory are not likely to be long sustained. High real prices deter consumption and encourage the emergence of significant competition from marginal but large sources of oil and non-oil energy supplies. Persistently low prices have the opposite effects. Limits to long-term oil price escalation include substitution of other fuels (such as natural gas) for oil, marginal sources of conventional oil that become reserves when prices rise, and nonconventional sources of oil that become reserves at still higher prices. Advances in exploration and production technologies are likely to bring down prices when such additional oil resources become part of the reserve base.

Highlights of the *IEO99* projection for the world oil market are as follows:

- The reference case price projection traces slow recovery over the next 3 to 4 years as growth in oil supply slows and demand growth resumes. The reference case rests on an assumption of economic recovery in various Asian countries in 2000 and beyond.

- Despite relative low prices in the near term, deepwater exploration and development initiatives are generally expected to be sustained worldwide, with offshore West Africa emerging as a major future source of oil production. Technology and resource availability can sustain large increments in oil production capability at prices ranging between \$18 and \$22 per barrel. The current price environment will, however, slow the pace of development in some highly prospective areas, including especially the Caspian Basin region.

- Economic development in Asia is crucial to long-term growth in oil markets. The projected evolution of oil demand will strengthen economic ties between the Middle East and Asian markets.

- Though OPEC's share of world oil supply is projected to increase significantly over the next two decades, competitive forces are expected to remain strong enough to forestall efforts to escalate real oil prices significantly. The competitive forces operate within OPEC, between OPEC and non-OPEC sources of supply, and between oil and other sources of energy (particularly natural gas).

- The uncertainties associated with the reference case projections presented here are significant. For example, although some signs of economic recovery in Asia are evident at the beginning of 1999, Japan's turnaround is still awaited. China's internal economic reforms may be at risk. Adverse ripple effects in South America seem to have gained some strength. Recovery prospects for the former Soviet Union have grown more dim. These and other economic strains increase the risk of near-term political and policy discontinuities that could lead to oil market behavior quite different from that portrayed in the *IEO99* projections.

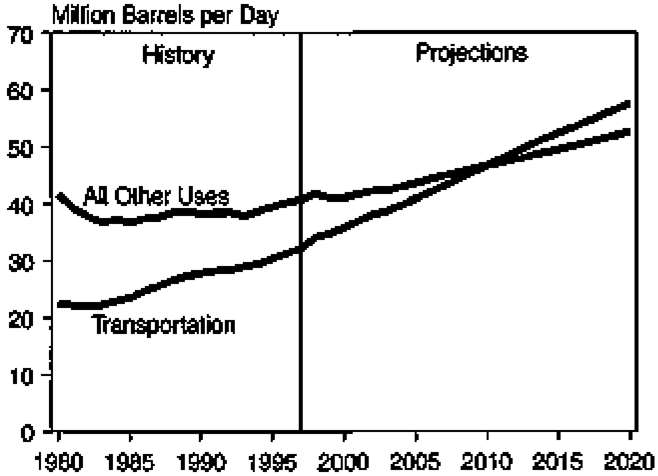
Growth in Oil Demand

Oil currently accounts for about 40 percent of world commercial energy supplies. The reference case projection anticipates rising demand, by about 1.8 percent per year, causing oil requirements to reach 110 million barrels per day by 2020.

In 2020, oil is expected to represent 37 percent of total energy supply. The decline in the energy share reflects primarily a trend toward switching to natural gas and other types of fuel particularly for power generation in many industrialized and developing countries. Oil demand in industrialized countries is projected to increase at only about 1 percent per year over the next two decades. Thus, the region that accounted for about 60 percent of oil demand in 1996 will account for only about one-third of anticipated demand growth between 1996 and 2020. The other two-thirds of demand growth (about 26 million barrels per day) is projected for developing countries. In Eastern Europe and the former Soviet Union (EE/FSU), domestic production and oil consumption have been in continuous decline since the late 1980s. A gradual turnaround is expected beyond 2000, but overall recovery expectations have been scaled back to less than 5 percent of the projected increase in world demand.

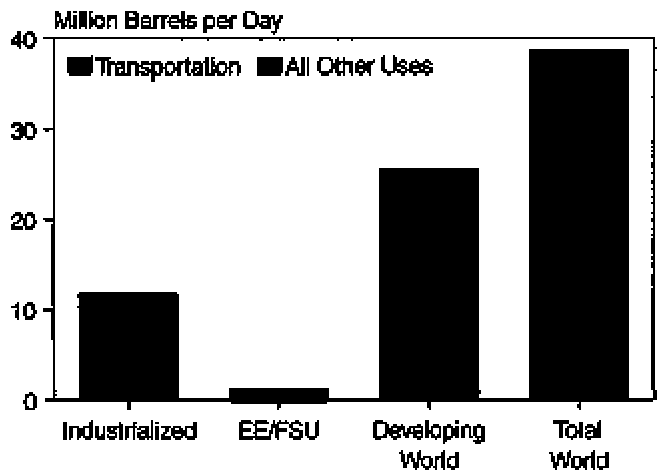
In all regions of the world, the largest increases in oil consumption are expected to result from oil's use as transportation fuel. After 2011, the use of oil used for transportation is projected to top all other uses combined (Figure 20). By 2020, transportation is expected to account for 52 percent of world oil consumption, up from a 44-percent share in 1996. The sources of growth in end-use consumption differ greatly between industrialized and nonindustrialized economies (Figure 21). In industrialized countries, oil demand growth stems almost exclusively from developments in transportation. In other areas, growing demand for petroleum fuels in electricity generation, heating, manufacturing, and other uses accounts for about one-third of the increment in oil consumption.

Figure 20. Petroleum Use for Transportation and Other Purposes, 1980-2020



Sources: **History:** Derived from Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

Figure 21. Projected Changes in Oil Consumption by Region, 2000-2020



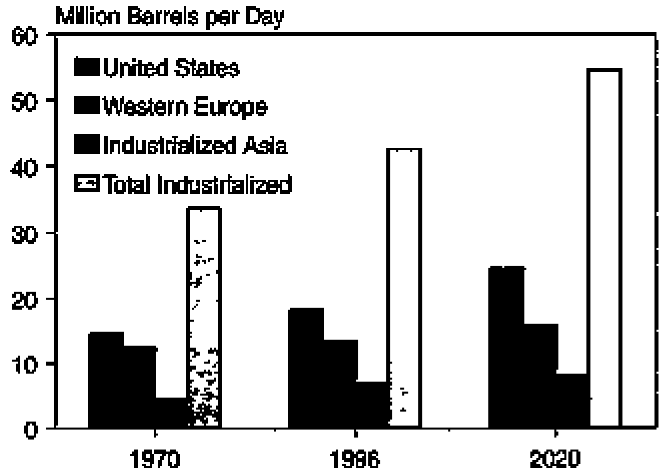
Source: Energy Information Administration, World Energy Projection System (1999).

Trends in Industrialized Economies

By the mid-1980s, many industrialized nations had reduced their reliance on oil in those applications where practical alternatives were available, such as electric utility and industrial boilers and home heating. The United States led the way in this transformation. European countries are expected to continue moving away from oil for nontransportation uses. Much of their prospective power capacity development involves increased reliance on natural gas at the expense of both oil and coal.

More than half the growth in oil consumption in industrialized countries (Figure 22) is projected to occur in the United States, where per capita car ownership and travel continue to rise. Western Europe represents about 20 percent of the growth in oil consumption, and Mexico and industrialized Asia (Japan, Australia, and New Zealand) each account for about 10 percent of the growth in industrialized oil consumption. A small amount of growth is projected for Canada. The projected increase in oil consumption in Japan is smaller in *IEO99* than it was in *IEO98* as a result of less optimistic economic assumptions in the current forecast.

Figure 22. Oil Demand in Industrialized Countries, 1970, 1996, and 2020



Sources: **1970 and 1996:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

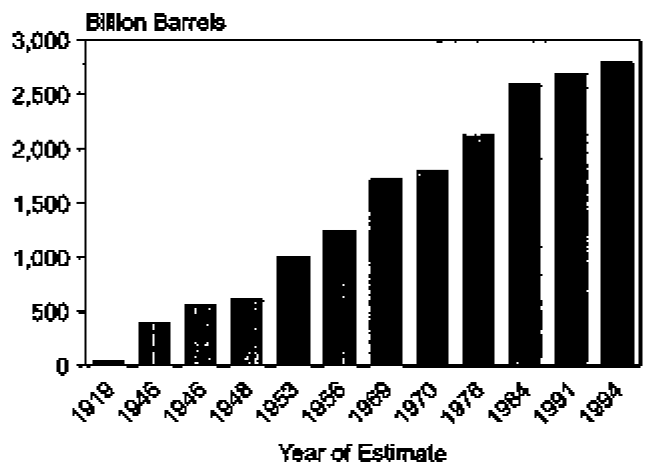
Trends in the EE/FSU and Developing Countries

Regional economics are expected to produce a 3.2-percent annual rise in oil consumption in newly industrializing (developing) countries and a much slower increase of about 0.8 percent per year in the EE/FSU region. The developing world, which accounted for less than one-third of the world's oil consumption in 1996, is expected to account for 44 percent of the oil market by 2020. Almost 50 percent of the growth in oil consumption in developing economies occurs in developing Asia (Figure 23). Although expectations for economic growth in developing Asia have been adjusted downward in *IEO99* to reflect the lingering economic crisis, the reference case projection continues to reflect strong potential for sustained economic growth. As a result, oil consumption in developing Asia, which accounted for 17 percent of world demand in 1996, expands to a 22-percent market share by 2020, comparable to the U.S. level. Within developing Asia, China, India, and South Korea are expected to more than double their 1996 oil consumption.

Are We Running Out of Oil?

Despite the optimism of the *IEO99* reference case with respect to long-term oil supply potential, it is not uncommon to find "gloom-and-doom" scenarios in publications or on the internet predicting that the world is imminently running out of oil. In this regard, it is instructive to look at the estimates of ultimately recoverable oil resources put together by "experts" within government, industry, and academia. Such efforts have been coordinated periodically by the U.S. Geological Survey (USGS) of the U.S. Department of Interior in its *World Petroleum Assessment and Analysis*. The USGS estimates of ultimately recoverable oil have been increasing since they were first made almost 50 years ago (see figure). This increasingly optimistic view of conventional oil resources represents only the beginning argument for why petroleum liquids are likely to remain a viable fuel well past the middle of the next century.

Estimates of the World Oil Resource Base, 1919-1994

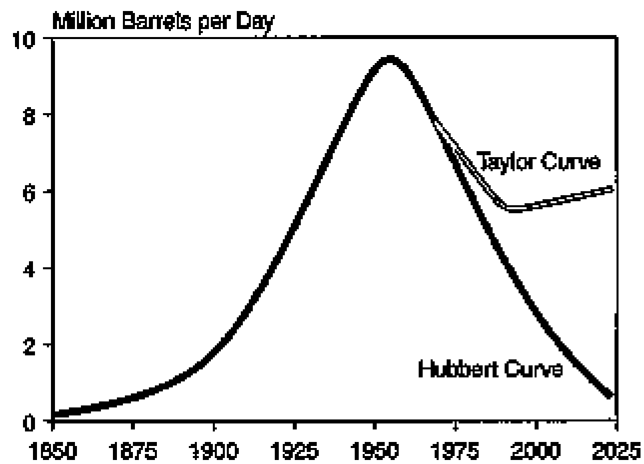


Source: U.S. Geological Survey, *World Petroleum Assessment and Analysis* (Washington, DC, various years).

In the mid-1950s, geophysicist M. King Hubbert suggested that any nonrenewable resource would follow a two-phase life cycle—a rise from zero to a peak, followed by a symmetric decline to zero. This is the classic, bell-shaped production cycle. In 1962, Hubbert used his hypothesis to estimate that U.S. production would peak in less than a decade. When domestic production took a downturn after 1970, Hubbert's views became the standard by which oil depletion issues were addressed. It soon became clear, however, that the simple logistic form proposed by Hubbert might be flawed. The declining side of the curve was not behaving symmetrically to the ascending side, apparently because the Hubbert methodology underestimated the post-peak quantity of oil.

Petroleum engineer Paul J. Taylor has devised an alternative methodology for understanding the depletion of the oil resource base. This methodology takes into account not only the physical aspects of an oil reservoir but also the consequences of economic, political, and technological developments. Taylor contends that history demonstrates that when demand exceeds supply, prices rise, technology improves, and production ceases to follow a Hubbert curve (see figure).

Alternative Oil Production Paths, 1850-2025



Source: P.J. Taylor, "Discussion of Modeling the U.S. Oil Industry: How Much Oil Is Left?" *Journal of Petroleum Technology*, paper SPE 52600 (May 1997).

It is important to emphasize that not all oil fields are equally receptive to economic or technological change. The Taylor curve depicted in the figure shows an oil production profile that will attain a secondary peak at some point after 2025 and then begin another decline. When all oil fields are being assessed, such a profile is decidedly optimistic. Geologic structures and physical limitations simply prevent certain oil fields from exhibiting anything but continual decline after a peak. On the other hand, even these oil fields can be receptive to economic or technological changes that ameliorate their rate of decline.

The most recent (1994) USGS assessment of worldwide oil resources estimated ultimate recoverable oil resources in the range of 2.1 to 2.8 trillion barrels. Currently, cumulative production and estimated proved reserves are both approximately 800 billion barrels, implying undiscovered oil resources in the range of 0.5 to 1.2 trillion barrels—an assessment which pessimistically assumes that the economics and technology of resource development and recovery will retain their 1994 regional attributes.

(continued on page 23)

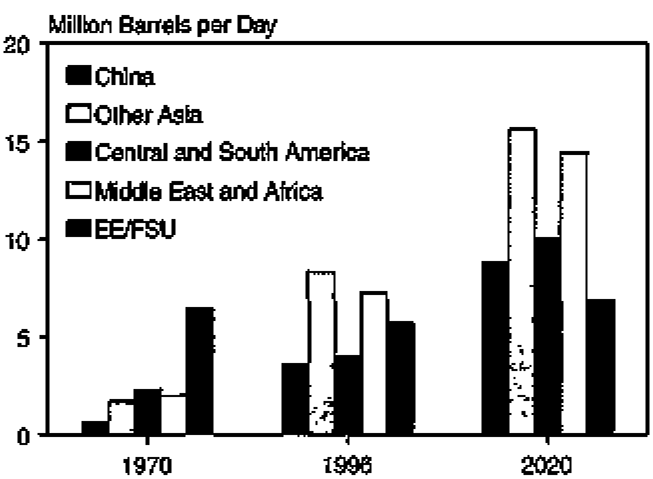
Are We Running Out of Oil? (Continued)

To see the restrictive effect of the USGS assumption, one need only look at the recovery efficiency for conventional oil. Whereas the average worldwide recovery rate is less than 35 percent, technologies now being applied in the North Sea and by many major U.S. producers regularly provide recovery rates in excess of 50 percent. It is estimated that for every 1-percent increase in average worldwide recovery efficiency, at least 50 billion barrels would be added to reserves. If 50 percent recovery were to become the worldwide average, more than 750 billion barrels of conventional oil would be added to reserves [3].

In the area of economics, one can look at the recovery of bitumen from the tar sands of western Canada. Canada has cut the production costs for oil from tar sands to less than $10 per barrel (although the capital investment remains substantial for putting in place the mining and extraction infrastructure) [4]. The recoverable bitumen from Canada and the heavy and extra-heavy oil from Venezuela are estimated to be at least 1 trillion barrels. An additional 15 trillion barrels of oil from shale is estimated worldwide, more than one-third of which is located in the United States. The technology to extract oil from shale exists but remains prohibitively expensive, particularly in the context of the *IEO99* price estimates. In the long run, however, as technology development improves the economics of exploiting such unconventional crude oil resources, the "unconventional" could eventually become conventional.

Bleak pictures painted of the world's remaining oil resource potential are based on current estimates of proven reserves and their decline in a Hubbert-like manner. When undiscovered oil, efficiency improvements, and the exploitation of unconventional crude oil resources are taken into account, it is difficult not to be optimistic about the long-term prospects for oil as viable energy source well into the future. Beyond that, the future of liquid fuels may reside in the gas-to-liquids conversion process that refines natural gas into high-quality middle distillates such as diesel, naphtha, kerosene, and jet fuel. Commercial demonstrations of such technologies are expected to emerge in the near future, and it is hoped that eventually they will be profitable even in a world of $12-per-barrel oil [5].

Figure 23. Oil Demand in Nonindustrialized Regions, 1970, 1996, and 2020



Sources: 1970 and 1996: Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). Projections: EIA, World Energy Projection System (1999).

China represents the largest growth area in developing Asia, with an increase of 5.2 million barrels per day between 1996 and 2020, slightly more than the combined increase for India and South Korea. Strong economic and population growth spur growth in oil consumption in the three countries. In China incremental oil demand is projected to come mostly from the transportation sector which is expected to grow at an annual average rate of 6.7 percent (compared with 1-percent annual growth in nontransportation uses). Demand for transportation fuels, especially diesel fuel, rise as railway and highway infrastructures are improved to allow for more personal and commercial travel. Road travel in China currently is limited by an underdeveloped roadway system and a level of per capita car ownership that is the lowest in Asia. Projected growth in oil demand is more evenly distributed between transportation and nontransportation uses in India and South Korea. In fact, nontransportation oil use, including consumption in the industrial, buildings, and electricity generation sectors, is projected to increase at a slightly faster rate than oil use for transportation in both India and South Korea.

Oil demand in Central and South America doubles over the forecast, but demand growth in the region is slightly slower than in other developing economies. As in other regions, transportation is the largest growth market in Central and South America, accounting for 70 percent of the projected increment in oil demand between 1996 and 2020. About 40 percent of the region's growth in total oil demand is expected in Brazil, which has the largest population and economy in the region. The reference case projection assumes that current Brazilian economic difficulties will soon ease.

Oil consumption patterns in the EE/FSU region are expected to continue the decline of the 1990s, set off by their transition to market economies. During the 1990s oil consumption declined along with gross domestic product in the EE/FSU nations, but it was forced even lower as supplies in oil-producing countries were exported to generate revenue. Consumption in the region is projected to begin to recover by 2005. By 2020, FSU consumption surpasses its 1996 levels—still only about 60 percent of the pre-depression 1990 level. In Eastern Europe oil consumption is projected to exceed 1996 levels by 2020, returning to levels of the early 1990s. Virtually all the region's growth in petroleum use results from increased demand for transportation fuel, as reliance on rail travel is replaced by highway travel. Residual fuel or "mazut," which is used heavily in industrial boilers and power plants, is expected to be replaced by inexpensive natural gas [6].

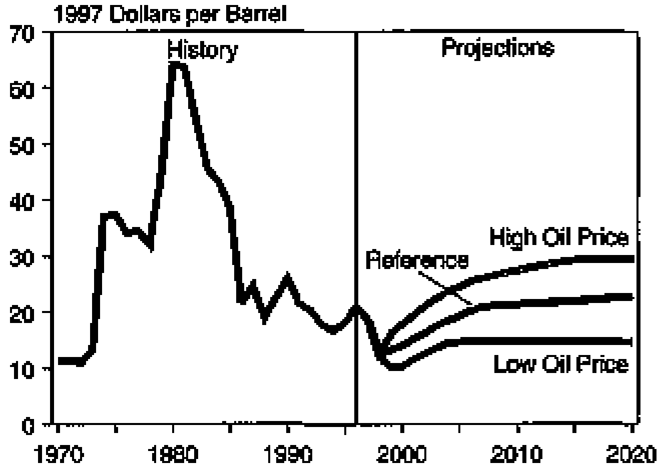
The Middle East and Africa account for 19 percent and 9 percent of the rise in oil demand within developing countries, respectively. Oil use for transportation rises rapidly in both regions. The transportation share of total petroleum demand rises from 27 percent to 33 percent in the Middle East and from 40 percent to 43 percent in Africa. The expected increases in nontransportation oil use in both regions are primarily for electricity generation.

World Oil Price

The near-term price trajectory in the *IEO99* reference case is considerably different from that in *IEO98*. The plummeting oil prices of 1998 were not anticipated last year, and the timing and magnitude of an expected rebound in both oil demand and oil prices are the source of much uncertainty. On the other hand, current price movements have not much affected the *IEO99* projections beyond 2005. Three possible long-term price paths are shown in Figure 24. The reference case forecast assumes rising real prices, at an annual rate of almost 6 percent from 1999 to 2007. After 2007, the *IEO99* reference case oil prices are similar to those in the *IEO98* reference case.

It should be noted that, regardless of the *IEO99* price scenario, oil demand rises significantly over the projection period. In the high and low world oil price cases, the projected rise in oil consumption ranges from a low of 32 million barrels per day to as much as 46 million barrels per day. There is now widespread agreement that resources are not a key constraint on world oil demand to 2020. Rather more important are the political, economic, and environmental circumstances that could shape developments in oil supply and demand.

Figure 24. World Oil Prices in Three Cases, 1970-2020



Sources: **History:** Energy Information Administration (EIA), *Annual Energy Review 1997*, DOE/EIA-0384(97) (Washington, DC, July 1998). **Projections:** EIA, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998).

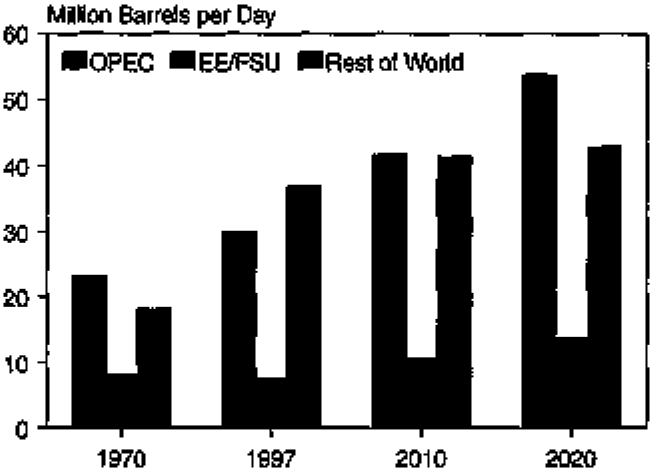
The Composition of World Oil Supply

The *IEO99* reference case projects an increase in world oil supply of more than 35 million barrels per day over the projection period. Gains in production are expected for both OPEC and non-OPEC producers; however, only about one-third of the production rise is expected to come from non-OPEC areas. Over the past two decades, the growth in non-OPEC oil supply has maintained OPEC's market share substantially under its historic high of 52 percent in 1973. New exploration and production technologies, aggressive cost-reduction programs by industry, and attractive fiscal terms to producers by governments all contribute to the outlook for continued growth in non-OPEC oil production.

While the long-term outlook for non-OPEC supply remains optimistic, the current low-price environment has had a definite impact on exploration and development activity. By October 1998, drilling activity in the United States had fallen by one-fourth from its level a year earlier. The decline in Canada was even sharper. Only the Middle East region registered no decline in activity during that period. In general, onshore drilling has fallen more sharply than offshore. Offshore rig utilization rates were generally sustained at levels better than 80 percent of capacity on a worldwide basis [7].

The reference case projection anticipates that almost two-thirds of the increase in demand over the next two decades will be met by increases in production by members of OPEC rather than by non-OPEC suppliers. OPEC production in 2020 is projected to be almost 24 million barrels per day higher than it was in 1997 (Figure 25). The *IEO99* estimate of OPEC production capacity for 2005 is more than 4 million barrels per day greater than that projected in *IEO98*, reflecting an unexpected shift away from non-OPEC supply projects in the current low-price environment to lower cost projects within OPEC areas (see box on page 26). Some analysts suggest that OPEC might pursue significant price escalation through conservative capacity expansion decisions rather than undertake ambitious production expansion programs. The view in this outlook discounts such suggestions.

Figure 25. World Oil Production in the Reference Case by Region, 1970-2020



Sources: **1970:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database. **1997:** EIA, *International Petroleum Statistics Report*, DOE/EIA-0520(98/11) (Washington, DC, November 1998). **Projections:** EIA, World Energy Projection System (1999).

Expansion of OPEC Production Capacity

It is generally acknowledged that OPEC members with large reserves and relatively low production capacity expansion costs can accommodate sizable increases in petroleum demand. In the *IEO99* reference case, the production call on OPEC producers grows at a robust annual rate of 2.6 percent (Table 6 and Figure 26). OPEC capacity utilization is expected to increase sharply after 2000, reaching 95 percent by 2010 and remaining there for the duration of the projection period.

Iraq's role in OPEC will be particularly interesting to observe over the next half-dozen years. For the purposes of the *IEO99* reference case, Iraq is expected to expand its oil production capacity to 2.8 million barrels per day by the year 2000, coinciding with the United Nations Security Council resolutions that allow Iraqi oil exports in excess of $5.2 billion in the first half of 1999. In the reference case, Iraqi oil exports are assumed to average

Table 6. OPEC Oil Production, 1990-2020
(Million Barrels per Day)

Year	Reference Case	High Oil Price	Low Oil Price
History			
1990	24.5	—	—
1997	29.8	—	—
Projections			
2000	31.0	29.2	33.4
2005	37.6	34.0	42.0
2010	41.5	36.6	48.9
2015	46.7	40.4	56.3
2020	53.5	46.7	65.0

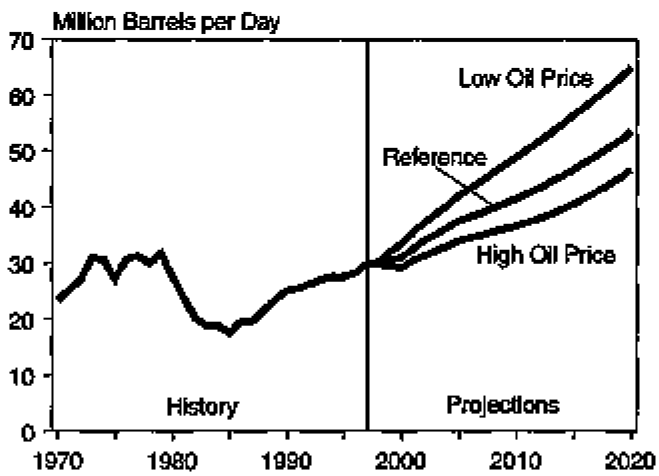
Note: Includes the production of crude oil, natural gas plant liquids, refinery gain, and other liquid fuels.

Sources: **History:** Energy Information Administration (EIA), *International Petroleum Statistics Report*, DOE/EIA-0520(98/11) (Washington, DC, November 1998), Table 1.4. **Projections:** EIA, World Energy Projection System (1999).

between 1.8 and 2.0 million barrels per day through 2000. Iraq has indicated a desire to expand its production capacity aggressively, to about 6 million barrels per day, when U.N. sanctions are lifted and has held talks with outside investors (including France, Russia, and China) about exploration deals. Such a significant increase in Iraqi oil exports would more than offset any price stimulus associated with current OPEC production cutbacks and would most likely dampen the price rebound assumed in the reference case.

Given the requirements for OPEC production capacity expansion implied by the *IEO99* estimates, much attention has been focused on the oil development,

Figure 26. OPEC Oil Production in Three Oil Price Cases, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

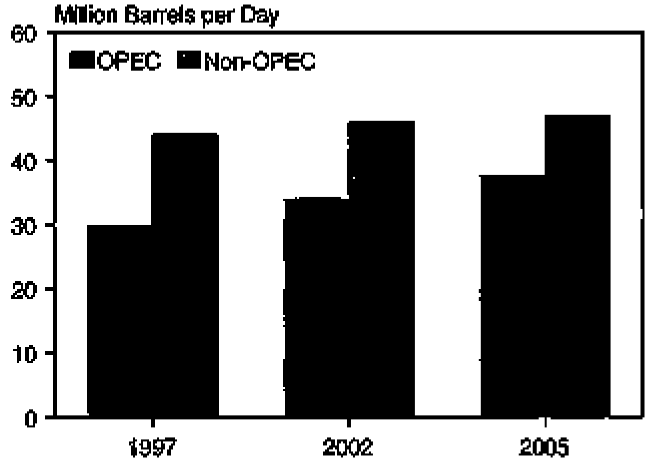
The Effects of Low Oil Prices on Worldwide Production Potential

The likely effects of the current low-price environment on worldwide oil production potential are most dramatically shown by the projected increase in OPEC market share over the next half-dozen years in the *IEO99* reference case. Following a small increase in 1999, limited by sluggish Asian demand and by anticipated increases in North Sea production, OPEC oil production is projected to rise markedly in the first half of the next decade. Projected OPEC production in 2005 is almost 8 million barrels per day higher than the 1997 level, compared with an increase of less than 3 million barrels per day for non-OPEC suppliers over the same period (see figure). The OPEC market share rises from just over 40 percent to almost 45 percent by 2005, as opposed to the OPEC market share of about 40 percent in 2005 that was projected in *IEO98*.

The shift in expected market share toward OPEC producers can be attributed largely to current low oil prices. More than three-quarters of all OPEC reserves can be produced at a cost (including exploration to replace extracted reserves, development, and operation) of less than $5 per barrel, and virtually all the remainder can be produced for less than $10 per barrel. In contrast, significant portions of the non-OPEC reserve base have production costs that exceed $11 per barrel [8]. Much of the higher cost non-OPEC production is in offshore areas, where deepwater exploration costs alone are about $40 million per well, compared with onshore exploration costs as low as $100,000 per well [9]. It should be noted that the difference between offshore and onshore exploration costs is considerably tempered by the fact that offshore finding rates are on the average significantly higher than onshore rates.

While U.S. and Canadian onshore exploration has been significantly curtailed by the current low price environment, much of the optimism regarding worldwide offshore activity is similarly showing a vulnerability to low prices. Declines in rig counts designated for deepwater exploration in the U.S. Texas Gulf, Canada, and

OPEC and Non-OPEC Oil Production, 1997, 2002, and 2005



Sources: **1997:** Energy Information Administration (EIA), *International Petroleum Statistics Report*, DOE/EIA-0520(98/11) (Washington, DC, November 1998). **Projections:** EIA, World Energy Projection System (1999).

(continued on page 27)

production, and operating costs of individual OPEC producers. With Persian Gulf producers enjoying a reserve- to-production ratio exceeding 80 years, substantial capacity expansion is obviously feasible.

Production costs in Persian Gulf OPEC nations are less than $1.75 per barrel. The capital investment required to increase production capacity by 1 barrel per day in Persian Gulf OPEC nations is less than $5,500 [10]. Assuming the *IEO99* low price trajectory, total development and operating costs over the entire projection period expressed as a percentage of gross oil revenues are less than 20 percent. Thus, Persian Gulf OPEC producers can expand capacity at a cost that is a relatively small percentage of projected gross revenues.

For OPEC producers outside the Persian Gulf, the cost to expand production capacity by 1 barrel per day is considerably greater, exceeding $10,000 in some member nations. However, even this group of producers can still expect margins in excess of 35 percent on investments to expand production capacity over the long term in even the low price case [11]. Venezuela has the greatest potential for capacity expansion and has aggressive plans to increase its production capacity to 4.6 million barrels per day by 2005. It is unclear, however, whether the newly elected regime will support the outside investment that would be required for any substantial expansion of production capacity. Tables D1-D10 in Appendix D show the ranges of production potential for both OPEC and non-OPEC producers.

The reference case projection implies aggressive efforts by OPEC member nations to apply or attract investment capital to implement a wide range of production capacity expansion projects. If those projects were not undertaken, world oil prices could escalate; however, the combination of potential profitability and the threat of competition from non-OPEC suppliers argues for the pursuit of an aggressive expansion strategy.

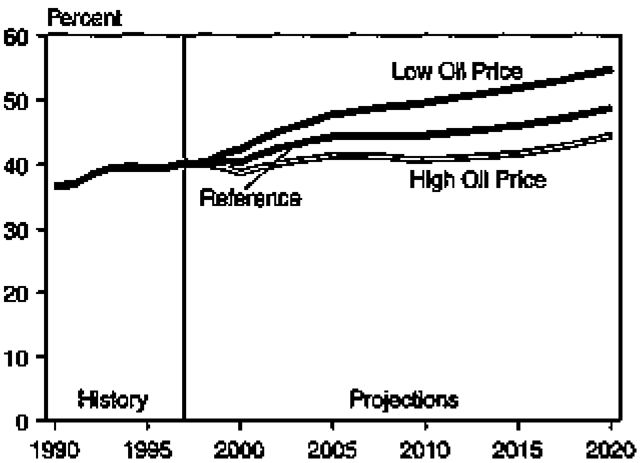
The Effects of Low Oil Prices on Worldwide Production Potential (Continued)

Mexico suggest that as much as 800,000 barrels per day of offshore production in North America, originally expected early in the next decade, could be delayed beyond 2005. Similarly, Latin American deepwater projects off Brazil and Colombia could account for an additional 300,000 barrels per day in delays. The enormous production potential in deepwater areas off the coast of western Africa, originally expected to produce more than 350,000 barrels per day by 2005, probably will not begin producing until after 2007. Similarly, Chinese, Thai, and Vietnamese interests in deepwater projects in the South China Sea are expected to delay more than 300,000 barrels per day of production until late in the next decade. *IEO98* projected production in the Caspian Basin region in excess of 2 million barrels per day by 2005, but significant delays in exploration and pipeline construction activity have made it doubtful that even 1.5 million barrels per day could be realized.

Much of the production from non-OPEC sources is light (high API gravity) and sweet (low sulfur) in comparison with OPEC Persian Gulf oil production. Therefore, a shift toward a greater OPEC market share implies an average barrel that is both heavier and more sour. High-quality transportation fuels, the demand for which increases substantially over the forecast period, are more difficult to produce in significant volumes from heavier and more sour crude oils. Worldwide refiners might find it necessary to add downstream processing units for upgrading the heavier, high-sulfur streams in order to produce transportation fuels. The current low-price environment could force a transition to more sophisticated refinery configurations sooner, rather than later, in the forecast period.

Beyond the year 2007, the *IEO99* price trajectory is similar to that in *IEO98*. It is expected that the delayed non-OPEC offshore projects will start producing significant volumes by 2010. The OPEC market share is projected to remain about level out to 2010 in the *IEO99* reference case, increasing steadily thereafter to a share of almost 49 percent in 2020 (see figure).

OPEC Oil Market Share in Three Oil Price Cases, 1990-2020



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

In *IEO99*, the non-Persian Gulf component of OPEC has been bolstered somewhat over the *IEO98* projections. There is still considerable optimism regarding Nigerian offshore production potential; however, such capacity is not likely to be developed until the middle to late part of the next decade. In addition, increased optimism regarding Algerian, Indonesian, and Venezuelan output has contributed to this reassessment. The non-Persian Gulf component of OPEC production is expected to show increases in output over the projection period that would result in a reduction in the world's dependence on Persian Gulf oil of between 4 percent and 7 percent from the *IEO98* estimates.

Non-OPEC Supply

The growth in non-OPEC oil supplies played a significant role in the erosion of OPEC's market share over the past two decades, as non-OPEC oil supply became increasingly diverse. North America dominated non-OPEC supply in the early 1970s, the North Sea and Mexico evolved as major producers into the 1980s, and much of the new production in the 1990s has come from the developing countries of Latin America and the non-OPEC Middle East as well as China. In the *IEO99* reference case, non-OPEC supply from proven reserves is expected to increase steadily, from 44.1 million barrels per day in 1997 to 56.3 million barrels per day in 2020 (Table 7).

There are several important differences between the *IEO99* production profiles and those published in *IEO98*:

- Despite significantly lower oil prices in the near term, the U.S. production decline is slightly less severe in the *IEO99* projections as a result of technological advances and increased offshore Texas Gulf production.
- Decreased rig activity in the North Sea is expected to delay peak production until after 2005; however,

Table 7. Non-OPEC Oil Production, 1990-2020
(Million Barrels per Day)

Year	Reference Case	High Oil Price	Low Oil Price
History			
1990.	42.2	—	—
1997.	44.1	—	—
Projections			
2000.	45.7	46.2	45.2
2005.	47.0	47.9	45.7
2010.	51.7	53.1	49.6
2015.	54.8	56.6	52.3
2020.	56.3	58.1	53.5

Note: Includes the production of crude oil, natural gas plant liquids, refinery gain, and other liquid fuels.

Sources: History: Energy Information Administration (EIA), *International Petroleum Statistics Report*, DOE/EIA-0520(98/11) (Washington, DC, November 1998), Table 1.4. Projections: EIA, World Energy Projection System (1999).

peak production is expected to be more than 0.5 million barrels per day greater in *IEO99* as a result of enhanced subsea technology.

- Resource development in the Caspian Basin region is significantly delayed. Whereas *IEO98* had Caspian output rising to 2 million barrels per day before the end of this century and increasing steadily thereafter, *IEO99* does not expect Caspian production levels to reach 2 million barrels per day until 2004. Political uncertainty still remains a potential barrier to the development of the vast resources in the region.

- There is still considerable optimism about the prospects for deepwater oil production worldwide, but significant output from such projects is not anticipated to start coming on line until prices return to the $18 to $20 per barrel range. Delays in some exploration and production activities for deepwater projects in the U.S. Texas Gulf, the North Sea, West Africa, the South China Sea, Colombia, and the Caspian Basin are expected in the face of the current low oil price environment.

In the *IEO99* forecast, North Sea production reaches a peak in 2006, exceeding 8 million barrels per day. Production from Norway, Western Europe's largest producer, is expected to peak at about 4.1 million barrels per day in 2005 and then gradually decline to about 3.3 million barrels per day by the end of the forecast with the maturing of some of its larger and older fields. The United Kingdom sector is expected to produce about 3.7 million barrels per day by the middle of the next decade, followed by a decline to about 2.5 million barrels per day by 2020.

Two non-OPEC Persian Gulf producers are expected to increase output gradually into the beginning of the next decade. Enhanced recovery techniques are expected to increase current output in Oman by almost 200,000 barrels per day, with only a modest production decline anticipated beyond 2005. Current oil production in Yemen could increase by at least 100,000 barrels per day early in the next century, and those levels could be maintained throughout the forecast period. Syria is expected to hold its production flat through most of the next decade but then reduce it steadily thereafter.

Oil producers in the Far East are beginning to reap the benefits of enhanced exploration and extraction technologies. India is expected to show a modest production increase into the next decade and exhibit very little decline in output thereafter. Deepwater fields offshore from the Philippines are expected to produce in excess of 200,000 barrels per day by 2004. There has been much optimism regarding the long-term production potential for Vietnam, where output is projected to exceed 450,000 barrels per day by 2020. Australian production is expected to peak at about 920,000 barrels per day by the middle of the next decade, but enhanced extraction technologies temper the production declines somewhat after 2005. Malaysia's output peaks at about 830,000 barrels per day by the turn of the century and declines gradually to about 650,000 barrels per day in 2020. Papua New Guinea achieves production volumes approaching 200,000 barrels per day by the middle of the next decade, followed by a steady decline over the remainder of the projection period. Exploration and test-well activity have indicated some production potential for Bangladesh and Mongolia, but significant output is not expected until the turn of the century.

Oil producers in Central and South America have significant potential for increasing output over the next decade. Within 5 years, both Brazil and Colombia are expected to join the relatively short list of worldwide producers whose output exceeds 1 million barrels per day. Colombia's output reaches almost 1.2 million barrels per day early in the next decade and remains at that level for the rest of the forecast. Brazil is viewed as having vast untapped production potential and, given a favorable climate for attracting foreign investment, could exceed 1.6 million barrels per day by 2020. Argentina is expected to raise its production levels by more than 100,000 barrels per day early in the next decade and could become a million barrel per day producer by 2005. Former OPEC member Ecuador is expected to increase its production capacity to allow additional output of more than 150,000 barrels per day.

Several West African producers (Angola, Cameroon, Chad, Congo, Gabon, Ivory Coast) could eventually reap the benefits of substantial offshore exploration activity when the oil price environment becomes more favorable. Angola is expected to more than double current output and be able to hold production levels of at least 1.7 million barrels per day over the projection period. The other West African producers are expected to increase output modestly for the remainder of the projection period. North African producers Tunisia and Egypt produce from mainly mature fields, which are likely to be in gradual decline after 2000. Sudan is expected to produce almost 200,000 barrels per day early in the next century. Other African producers with output potential that will probably not be fully realized before 2005 include Equatorial Guinea, Eritrea, Somalia, and South Africa.

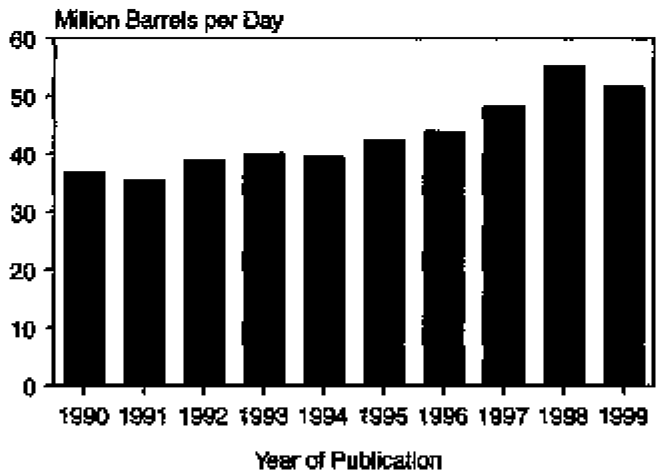
In North America, falling U.S. output is expected to be more than offset by production increases in Canada and Mexico. Canada's projected output increases by more than 200,000 barrels per day by the end of the decade, mainly from Newfoundland's Hibernia oil project, which could produce 150,000 barrels per day at its peak, some time near the turn of the century. Canada adds an additional 600,000 barrels per day in output from a combination of frontier area offshore projects and oil from tar sands. Offshore discoveries in the Gulf of Mexico, incremental Alaskan production from Cook Inlet, and technological advances in extraction methods temper the projected decline in U.S. production. Mexico is expected to adopt energy policies that encourage the efficient development of its vast resource base, with expected production volumes approaching 4 million barrels per day by 2010 and showing very little decline for the remainder of the projection period.

Oil production in the FSU is expected to reach 7.6 million barrels per day by 2005—1.9 million barrels per day less than projected in *IEO98* as a result of delays in the startup of many Caspian Basin projects as well as a pessimistic outlook for investment interest in Russia. Optimism remains high regarding long-term FSU production potential, and output is expected to exceed 13 million barrels per day by 2020. Thus, by the end of the forecast period, the FSU would be a net exporter of more than 7.9 million barrels per day. Much of the FSU export potential is in the resource-rich Caspian Sea region. While China's oil production is expected to increase steadily to more than 3.6 million barrels per day by 2015, it will find itself importing large volumes of petroleum to meet burgeoning domestic demand.

The estimates for non-OPEC production potential presented in this outlook are based on such parameters as numbers of exploration wells, finding rates, reserve-to-production ratios, advances in both exploration and extraction technologies, and the world oil price. It should be noted that non-OPEC production potential could be significantly greater if no constraints were placed on the exploration and development of undiscovered resources. For the purpose of the *IEO98* reference case, low oil price, and high oil price assessments, no more than 15 percent of the mean USGS estimate of undiscovered oil was allowed to be developed over the forecast period. Tables D1-D10 in Appendix D show the ranges of production potential for both OPEC and non-OPEC producers.

The expectation in the late 1980s and early 1990s was that non-OPEC production in the longer term would remain stagnant or gradually decline in response to resource constraints. The relatively insignificant cost of developing oil resources within OPEC countries (especially those in the Persian Gulf region) was considered such an overwhelming advantage that non-OPEC production potential was viewed with considerable pessimism. In actuality, however, despite a relatively low oil price environment, non-OPEC production has risen every year since 1993, adding almost 4 million barrels per day during that period. In the coming decade it is expected that non-OPEC producers will continue to increase output, producing an additional 7.5 million barrels per day by 2010. Three factors are generally give credit for the impressive resiliency of non-OPEC production: development of new exploration and production technologies, efforts by the oil industry to reduce costs, and efforts by producer governments to promote exploration and development by encouraging outside investors with attractive fiscal terms. As has been the case with so many other forecasters of oil market attributes, the Energy Information Administration has found the estimation of future non-OPEC oil production to be particularly unstable over the past decade (Figure 27).

Figure 27. *IEO* Projections of 2010 Non-OPEC Oil Production, 1990-1999



Sources: Energy Information Administration, *International Energy Outlook*, DOE/EIA-0484 (Washington, DC, various years).

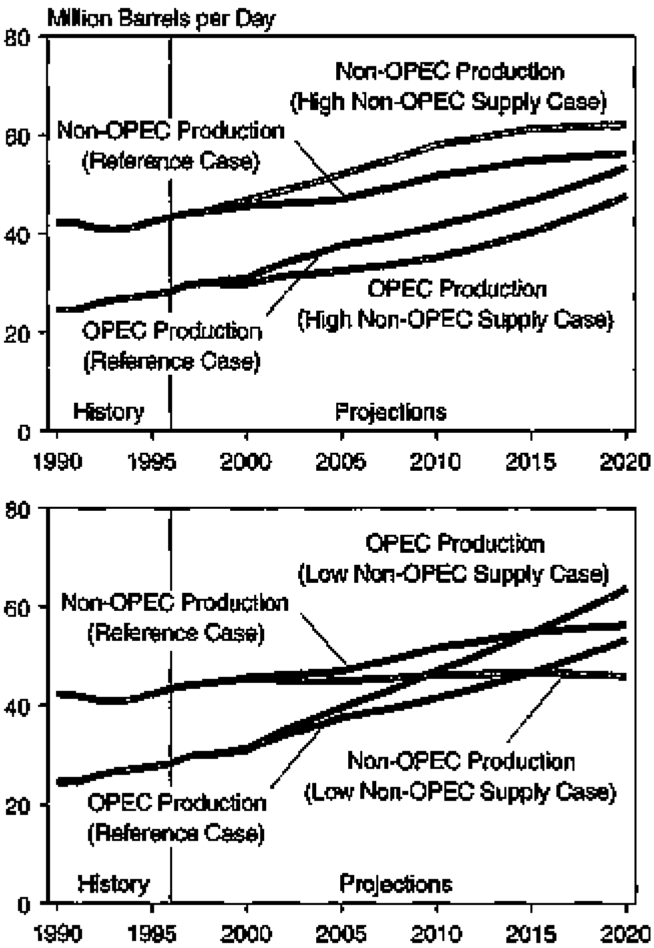
Alternative Non-OPEC Supply Cases

The only variable affecting the estimates of non-OPEC production potential in the alternative case described above is the world oil price assumption. As a result, the range in non-OPEC supply is modest, varying by only slightly more than 4.6 million barrels per day at the end of the forecast period. In fact, improved technology and better understanding of the underlying resource potential have been major factors sustaining non-OPEC supply in the recent past. To examine the effects of those factors, two additional cases—the high and low non-OPEC supply cases were developed for *IEO99*. Figure 28 compares OPEC and non-OPEC production estimates in the reference case with those in the two alternative non-OPEC supply cases. The alternative cases used reference case assumptions except for the following departures.

High Non-OPEC Supply Case:

- Due to increased optimism regarding the offshore production potential in the FSU, Latin America, West Africa, and the South China Sea, undiscovered oil in those regions is assumed to be 15 percent greater than the estimates in the reference case.

Figure 28. OPEC and Non-OPEC Oil Production in Three Cases, 1990-2020



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

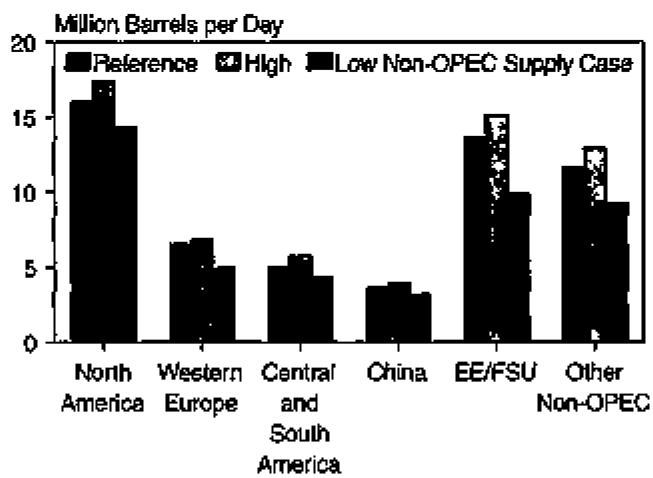
- One-third of the world's (non-OPEC, non-U.S.) undiscovered oil is considered economical to develop over the forecast period.
- Technology improvements over the forecast period are assumed to be transferrable worldwide.
- A reserve-to-production ratio of 15 years (slightly less than the current non-OPEC ratio) is used as a lower bound for production estimates.

Low Non-OPEC Supply Case:

- The amount of oil production from undiscovered reserves in deepwater areas is assumed to be 25 percent less than the reference case estimate as a result of persistent low oil prices and the finding of more natural gas deposits than oil deposits.
- Only one-fifth of the undiscovered oil in non-OPEC areas is considered economical to develop over the forecast period.
- There are assumed to be no significant technology improvements over the forecast period, and worldwide oil recovery rates are assumed to average only 35 percent.
- Russia's oil production is assumed to be one-third of that estimated in the reference case.

The high non-OPEC supply case assumptions result in 1.5-percent annual growth in non-OPEC production over the forecast period, as compared with a 1.1-percent growth rate in the reference case. Non-OPEC oil production reaches a peak of 62.1 million barrels per day in the high case in 2020, compared with a peak of 56.3 million barrels per day in the reference case. Figure 29 compares peak production levels for six non-OPEC regions in the reference, high, and low non-OPEC supply cases.

Figure 29. Non-OPEC Oil Production by Region in Three Cases, 2020



Source: Energy Information Administration, World Energy Projection System (1999).

In the reference case, OPEC production peaks at 53.5 million barrels per day, and the OPEC share of worldwide production reaches almost 49 percent by 2020. In the high non-OPEC supply case, OPEC production peaks at 48.0 million barrels per day and never assumes a market share above 44 percent. The low non-OPEC supply case projects only modest 0.2-percent annual growth in non-OPEC production over the forecast period. Non-OPEC production peaks in 2015 at 46.7 million barrels per day. OPEC production reaches 64 million barrels per day in 2010, achieving a majority share of the world market, and exceeds 58 percent of the world's total production in 2020.

Worldwide Petroleum Trade in the Reference Case

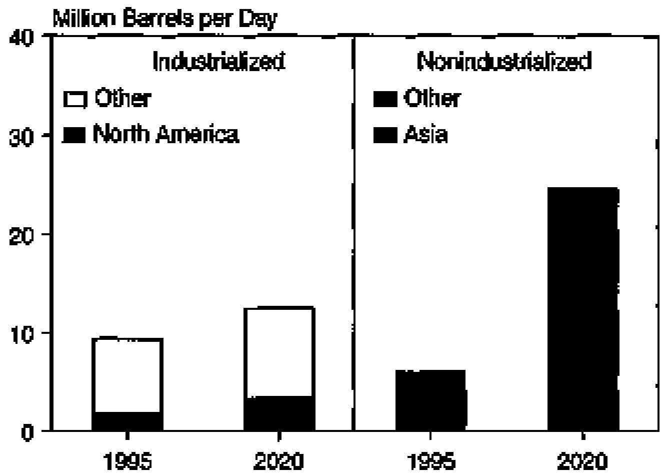
In 1995, industrialized countries imported 15.8 million barrels of oil per day from OPEC producers. Of that total, 9.4 million barrels per day came from the Persian Gulf region. Oil movements to industrialized countries represented more than two-thirds of the total petroleum exported by OPEC member nations and more than 60 percent of all Persian Gulf exports (Table 8). By the end of the forecast period, OPEC exports to industrialized countries are estimated to be almost 6 million barrels per day higher than their 1995 level, and more than half the increase is expected to come from the Persian Gulf region.

Despite such a substantial increase, the projected share of total petroleum exports in 2020 that goes to the industrialized nations is considerably lower than their 1995 share, at slightly over 54 percent. Their share of all Persian Gulf exports falls even more dramatically, to around 33 percent. This significant shift in the balance of OPEC export shares between the industrialized and nonindustrialized nations is a direct result of the robust economic growth anticipated for the developing nations of the world, especially those of Asia. OPEC petroleum exports to developing countries are expected to increase by almost 20 million barrels per day over the forecast period, with about half the increase going to the developing countries of Asia. China, alone, will most likely import about 4.6 million barrels per day from OPEC by 2020, virtually all of which is expected to come from Persian Gulf producers.

North America's petroleum imports from the Persian Gulf are expected to increase by almost 90 percent over the forecast period (Figure 30). At the same time, more than half of total North American imports in 2020 are expected to be from Atlantic Basin producers and refiners, with significant increases in crude oil imports anticipated from Latin American producers, including Venezuela, Brazil, Colombia, and Mexico. West African producers, including Nigeria and Angola, are also expected to increase their export volumes to North America. Caribbean Basin refiners are expected to account for most of the increase in North American imports of refined products.

With a moderate decline in North Sea production, Western Europe is expected to import increasing amounts from Persian Gulf producers and from OPEC member nations in both northern and western Africa. Substantial imports from the Caspian Basin are also expected. Industrialized Asian nations are expected to increase their already heavy dependency on Persian Gulf oil. The developing countries of the Pacific Rim are expected to more than double their total petroleum imports between 1995 and 2020.

Figure 30. Imports of Persian Gulf Oil by Importing Region, 1995 and 2020



Sources: 1995: Energy Information Administration (EIA), Office of Energy Markets and End Use, Energy Markets and Contingency Information Division. 2020: EIA, Office of Integrated Analysis and Forecasting, WORLD Reference Model (1999).

Worldwide crude oil distillation refining capacity was 78.3 million barrels per day at the beginning of 1997. To meet the projected growth in international oil demand in the reference case, worldwide refining capacity will have to increase by more than 40 million barrels per day by 2020. Substantial growth in distillation capacity is expected in the Middle East, Central and South America, and especially in the Asia Pacific region. Refiners in North America and Europe, while making only modest additions to their distillation capacity, are expected to continue improving product quality and enhancing the usefulness of the heavier portion of the barrel through investment in downstream capacity. Likewise, future investments by developing countries are also expected to include more advanced configurations designed to meet the anticipated increase in demand for lighter products.

Table 8. Worldwide Petroleum Trade in the Reference Case, 1995 and 2020
(Million Barrels per Day)

Exporting Region	Importing Region: Industrialized: North America	Western Europe	Asia	Total	Nonindustrialized: Pacific Rim	China	Rest of World	Total
	1995							
OPEC								
Persian Gulf	1.8	3.4	4.2	9.4	4.1	0.4	1.5	6.0
North Africa	0.3	1.9	0.0	2.2	0.0	0.0	0.1	0.1
West Africa	1.0	0.6	0.1	1.7	0.3	0.0	0.1	0.4
South America	1.6	0.3	0.0	1.9	0.1	0.0	0.6	0.7
Asia	0.1	0.0	0.5	0.6	0.1	0.0	0.0	0.1
Total OPEC	4.8	6.2	4.8	15.8	4.6	0.4	2.3	7.3
Non-OPEC								
North Sea	0.7	3.4	0.1	4.2	0.0	0.0	0.4	0.4
Caribbean Basin	2.8	0.3	0.1	3.2	0.1	0.0	0.9	1.0
Former Soviet Union	0.0	1.6	0.0	1.6	0.3	0.0	0.7	1.0
Other Non-OPEC	0.6	0.2	1.1	1.9	0.1	0.2	0.4	0.7
Total Non-OPEC	4.1	5.5	1.3	10.9	0.5	0.2	2.4	3.1
Total Petroleum Imports	8.9	11.7	6.1	26.7	5.1	0.6	4.7	10.4
	2020							
OPEC								
Persian Gulf	3.4	3.5	5.6	12.5	9.9	4.6	10.2	24.7
North Africa	0.3	1.9	0.1	2.3	0.1	0.0	0.2	0.3
West Africa	1.7	0.9	0.3	2.9	0.1	0.0	0.1	0.2
South America	2.8	0.7	0.1	3.6	0.1	0.0	0.6	0.7
Asia	0.0	0.0	0.2	0.2	0.1	0.0	0.0	0.1
Total OPEC	8.2	7.0	6.3	21.5	10.3	4.6	11.1	26.0
Non-OPEC								
North Sea	0.9	2.7	0.0	3.6	0.1	0.0	0.4	0.5
Caribbean Basin	3.3	0.2	0.1	3.6	0.1	0.0	1.5	1.6
Former Soviet Union	0.4	2.7	0.4	3.5	0.4	0.4	0.7	1.5
Other Non-OPEC	2.4	0.9	0.2	3.5	0.1	0.2	0.4	0.7
Total Non-OPEC	7.0	6.5	0.7	14.2	0.7	0.6	3.0	4.3
Total Petroleum Imports	15.2	13.5	7.0	35.7	11.0	5.2	14.1	30.3

Notes: Totals may not equal sum of components due to independent rounding.

Sources: 1995: Energy Information Administration (EIA), Energy Markets and Contingency Information Division. 2020: EIA, Office of Integrated Analysis and Forecasting, WORLD Reference Model (1999).

Other Views of Prices and Production

Several oil market analysis groups produce world oil price and oil production projections. Table 9 compares the *IEO99* world oil price projections with similar forecasts from Standard and Poor's DRI (DRI), the International Energy Agency (IEA), Petroleum Economics, Ltd. (PEL), Petroleum Industry Research Association, Inc. (PIRA), the Gas Research Institute (GRI), National Resources Canada (NRCan), WEFA Energy (WEFA), and BT Alex.Brown, Inc. (BTA).

The collection of forecasts includes a wide range of price projections, particularly for 2000—doubtless because of differing views about when the world oil price will recover from the 10- to 20-year lows set in 1998. *IEO99*

Table 9. Comparison of World Oil Price Projections, 2000-2020
(1997 Dollars per Barrel)

Forecast	2000	2005	2010	2015	2020
IEO99					
Reference Case	13.11	19.25	21.30	21.91	22.73
High Price Case	17.90	24.53	27.33	29.14	29.35
Low Price Case	10.25	14.57	14.57	14.57	14.57
DRI (April 1998)	15.55	16.94	19.06	21.44	24.13
IEA (November 1998)	20.27	20.27	20.27	29.81	29.81
PEL (December 1998)	14.31	13.42	12.03	10.12	–
PIRA (October 1998)	16.55	17.80	19.45	–	–
WEFA (February 1998)	18.27	19.04	19.75	20.52	21.32
GRI (November 1998)	17.87	16.86	16.81	17.02	–
NRCan (April 1997)	20.76	20.76	20.76	20.76	20.76
BTA (January 1999)	15.00	18.00	18.00	18.00	18.00

Notes: *IEO99* projections are for average landed imports to the United States. DRI, GRI, WEFA, and BTA projections are for composite refiner acquisition prices. PEL projections are for Brent crude oil. PIRA projections are for West Texas Intermediate crude oil at Cushing.

Sources: ***IEO99***: Energy Information Administration, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998). **DRI**: DRI/McGraw-Hill, *World Energy Service: U.S. Outlook* (Lexington, MA, April 1998), p. 70. **IEA**: International Energy Agency, *World Energy Outlook 1998* (Paris, France, 1998), p. 84. **PEL**: Petroleum Economics, Ltd., *Oil and Energy Outlook to 2015* (London, United Kingdom, December 1998), p. 57. **PIRA**: PIRA Energy Group, *Retainer Client Seminar* (New York, NY, October 1998), Table II-3. **WEFA**: WEFA Group, *U.S. Energy Outlook 1998* (Eddystone, PA, February 1998), p. 4.15. **GRI**: Gas Research Institute, *1999 Data Book of the GRI Baseline Projections of U.S. Energy Supply and Demand to 2015* (Washington, DC, November 1998), p. SUM-21. **NRCan**: Natural Resources Canada, *Canada's Energy Outlook, 1996-2020*, Annex C2 (Ottawa, Ontario, Canada, April 1997). **BTA**: BT Alex.Brown, Inc., "World Oil Supply and Demand Estimates," e-mail from Adam Sieminski (January 27, 1999).

and PEL expect world oil prices to remain low through 2000, at $13.11 and $14.31, respectively, in constant 1997 U.S. dollars per barrel. However, prices among the different series run into the $20s, with the highest being $20.76 for NRCan in 2000. The NRCan price expectations may be somewhat dated in comparison with the other forecasts, because they were published in April 1997, before the economic crisis hit Southeast Asia. On the other hand, the IEA prices for 2000 are also on the high side ($20.27 per barrel in 2000), and they were developed after the Asian recession began.

The IEA price projections are generally higher than the other forecasts throughout the projection period. *IEO99* also tends to be on the high end of the price ranges. The oil price projections for 2005 vary from $13.42 constant 1997 U.S. dollars per barrel (PEL) to $20.76 (NRCan), with *IEO99* at $19.25. In 2010, *IEO99* has the highest world oil price of any of the forecasters at $21.30, compared with the low-end price from PEL of $12.03.

PEL (after 2000) and IEA (after 2010) may be considered outliers among the collection of forecasts. PEL's price projections fall below the *IEO99* low price case in every year between 2005 and 2015, when the PEL forecast ends. Similarly, after 2010, IEA price expectations exceed the *IEO99* high oil price case. In 2015, the last year for which prices projections are available from both of these forecasters, the range between highest price (IEA at $29.81 per barrel) and lowest price (PEL at $10.12 per barrel) is almost $20. Omitting the IEA and PEL price series, the range of prices among the remaining forecasters is much smaller for the 2005-2020 period. In 2015, for example, the prices among the remaining forecasters range from GRI's low of $17.02 per barrel to *IEO99*'s high of $21.91, a difference of $4.89. When PEL and IEA are included, the range is far greater at $19.69 (the difference between $10.12 per barrel for PEL and $29.81 for IEA).

The spread of world oil price projections grows after 2000, demonstrating the increasing uncertainty as the time horizon expands. Aside from PEL and IEA, all the forecasts fall within the bands defined by the *IEO99* high and low price trajectories, with only two exceptions. In 2000, price projections for both NRCan (at $20.76 per barrel) and WEFA (at $18.27 per barrel) are higher than the *IEO99* high case price ($17.90 per barrel).

The price forecasts are influenced by differing views of the projected composition of world oil production. Two factors are of particular importance: (1) expansion of OPEC oil production and (2) the timing of a recovery in EE/FSU oil production. All the forecasters agree that recovery in EE/FSU oil production will be fairly slow (Table 10). The share of EE/FSU oil production does not

Table 10. Comparison of World Oil Production Forecasts

Forecast	Percent of World Total			Million Barrels per Day		
	OPEC	EE/FSU	Rest of World	OPEC	EE/FSU	Rest of World
History						
1996	39	10	50	28.3	7.3	36.2
Projections						
2000						
IEO99	40	10	50	31.0	7.6	38.0
DRI[a]	41	8	50	31.0	6.2	37.8
PEL	40	10	50	30.3	7.5	37.5
PIRA	37	9	53	28.8	7.1	41.3
BTA	41	10	49	31.0	7.4	36.8
2005						
IEO99	44	9	46	37.6	7.9	39.0
DRI	38	8	54	31.7	6.7	45.2
PEL	40	11	49	33.4	8.8	40.6
PIRA	38	10	52	32.6	8.5	44.8
BTA	45	11	45	37.9	8.9	37.8
2010						
IEO99	45	11	44	41.5	10.5	41.2
DRI	39	7	54	36.2	7.0	50.1
IEA[b]	47	11	42	43.8	10.2	38.7
PEL	43	12	45	39.4	10.8	41.1
PIRA	40	11	49	37.8	10.5	46.5
BTA	47	11	42	44.4	10.5	39.0
2015						
IEO99	46	12	42	46.7	12.5	42.3
DRI	41	7	52	42.5	7.3	53.2
BTA	49	12	40	50.4	12.2	41.0
2020						
IEO99	49	12	39	53.5	13.6	42.7
DRI	42	7	51	47.5	7.5	58.2
IEA[b]	55	10	35	49.0	9.4	31.5
BTA	50	12	38	57.1	14.1	43.5

[a]In the DRI projections, EE/FSU includes only the former Soviet Union.
[b]In the IEA projections, OPEC includes only Middle East OPEC.
Note: Percentages may not add to 100 due to independent rounding.
Sources: ***IEO99***: Energy Information Administration, World Energy Projection System (1999) and "DESTINY" International Energy Forecast Software (Dallas, TX: Petroconsultants, 1999). **DRI**: DRI/McGraw-Hill, *World Energy Service: Oil Market Outlook 1998* (Lexington, MA, October 1998). **IEA**: International Energy Agency, *World Energy Outlook 1998* (Paris, France, November 1998), p. 101 and p. 117. **PEL**: Petroleum Economics, Ltd., *Oil and Energy Outlook to 2015* (London, United Kingdom, December 1998), Table 7. **PIRA**: PIRA Energy Group, *Retainer Client Seminar* (New York, NY, October 1998). **BTA**: BTA Alex.Brown, fax from Adam Sieminski (December 11, 1998).

exceed 12 percent over the entire projection period in any forecast included here. DRI is least optimistic about recovery in this region, and its projection for the EE/FSU share of world oil production never exceeds 8 percent. Indeed, DRI's forecast of Russia's share of world oil production (oil production estimates for the entire region are not available from DRI) falls to 7 percent after 2005 and remains there through 2020. PEL is the most optimistic about EE/FSU oil production, projecting an increase from 10 percent of world production in 2000 to 12 percent in 2010. *IEO99* and BTA expect the EE/FSU share to increase to 12 percent by 2015, where it remains through 2020.

The forecasts that provide projections through 2020 (*IEO99*, DRI, BTA, and IEA) expect OPEC to provide an increment of between 20 and 30 million barrels per day between 1996 and 2020. There is more variation in expectations among these four forecast services for the "other," non-OPEC suppliers. Only DRI expects other suppliers to provide a larger increment of oil over the 1996-2020 time period than the OPEC suppliers. In contrast, IEA expects production from other suppliers to decrease by about 5 million barrels per day over the projection period. IEA expects the "other" share of world oil production to fall to 35 percent by 2020, while OPEC's share of world oil production grows to 55 percent. (The IEA estimate for the OPEC share is actually *understated*, because IEA does not publish oil production forecasts for the entire OPEC but only for "Middle East" OPEC. With non-Persian Gulf OPEC members supplying about 35 percent of OPEC's current production, it can be assumed that the total OPEC share of world oil production in the IEA forecast is even higher in 2020 than the 55 percent shown in Table 10.) *IEO99* and BTA similarly project that "other" non-OPEC supply will increase by around 7 million barrels per day by 2020.

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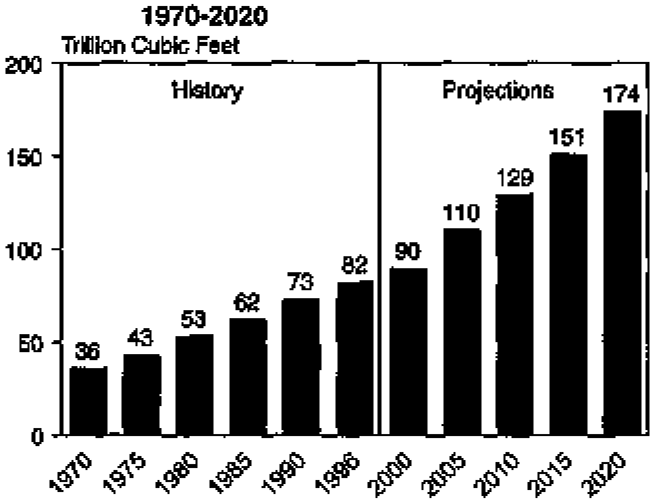
Natural Gas

Natural gas is the fastest growing primary energy source in the IEO99 forecast. Because it is a cleaner fuel than oil or coal and not as controversial as nuclear power, gas is expected to be the fuel of choice for many countries in the future.

Prospects for natural gas demand worldwide remain bright, despite the impact of the Asian economic recession on near-term development. Natural gas consumption in the *International Energy Outlook 1999* (*IEO99*) is somewhat increased from last year's outlook, and the fuel remains the fastest growing primary energy source in the forecast period. Worldwide gas use more than doubles in the reference case projection, reaching 174 trillion cubic feet in 2020 from 82 trillion cubic feet in 1996 (Figure 31). Strongest growth is projected in the developing countries of Central and South America and Asia, but large incremental increases in demand are projected for industrialized countries as well.

Figure 31. World Natural Gas Consumption, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

In the industrialized countries, where gas markets are most mature, gas use is projected to grow by 2.2 percent over the 24-year projection period, more than twice as fast as the projected growth rate for oil consumption. Many industrialized countries view natural gas as a way to reduce greenhouse gas emissions and, as a result, are expected to expand their use of gas. Because natural gas is a cleaner fossil fuel than oil or coal and is not as controversial as nuclear power, it is expected to be the fuel of choice for many industrialized countries in the future.

Developing countries are also interested in the environmental benefits of using natural gas, but often they are more intent on using natural gas to diversify fuel mix. In particular, countries of Central and South America are expanding gas-fired electricity generation capacity at a rapid pace in an effort to diversify electricity sources. Heavy dependence on the non-emitting hydroelectric resources in the region has led to problems in maintaining the electricity supply in times of drought. Hydroelectricity and other renewable resources accounted for 77 percent of the energy consumed for electricity generation in Central and South America in 1996; by 2020 the share is projected to fall to 53 percent because of expanded natural gas use.

In developing Asia, the news regarding gas markets has been mixed, an obvious result of the economic crisis that began in 1997 and continued throughout 1998. Various projects have been delayed or scaled back. In Thailand, for example, the state power company reduced expected investment in gas projects by 30 percent for the 1998-2006 period. Activity in Indonesia has been hit even harder. On the other hand, there is fresh optimism that China will build a liquefied natural gas (LNG) regasification project in Guangdong, and there has been movement in the development of LNG projects in India—such as Enron's finalized agreement to purchase LNG from Oman for its Dabhol power project.

Other major developments in natural gas markets in 1998 include:

- Several important pipelines were either completed or under construction in Central and South America in 1998. The first Uruguay-Argentina pipeline connection became operational. Progress was also made on the Bolivia-to-Brazil line, as well as on two Argentina-to-Brazil lines, Gas Atacama and Norandino. Negotiations are underway to get another pipeline connection between Argentina and Brazil via a planned 1,900-mile Mercosur pipeline.

- Progress on the Camisea gas fields in Peru stumbled somewhat at the end of 1998, with Shell and Mobil withdrawing from the project. As a result, tenders for field development were re-offered. It is still likely, however, that development of the vast 11 to 20 trillion cubic feet of estimated natural gas reserves in the Camisea fields will occur in the near future.

- Growth of Western Europe's gas infrastructure continued apace in 1998. Two major offshore pipeline systems, the Interconnector—running from England to Belgium—and the NorFra—running from Norway's North Sea fields to France—began operating. Onshore construction on several major lines was completed: the Artere des Hauts-de-France, France's largest on-land gas pipeline; the trans-Belgium VTN-RTR pipeline; and Germany's Wedel line, which runs across western Germany. Altogether, these pipelines represent a $2.7 billion investment in European gas infrastructure.

- Nigeria has taken steps toward reducing the amount of natural gas flared during oil production—which currently accounts for about three-fourths of all gas produced by the country. In 1997, the first phase of the three-phase Escravos project was completed. The $550 million project provides 165 million cubic feet of natural gas per day for domestic consumption. The second phase of the project will provide the first gas to Ghana as part of the West African Gas Pipeline; the third phase may be used to supply gas for the Chevron-Sasol gas-to-liquids project. By 2004, Nigeria expects to virtually eliminate gas flaring.

- The Russian government, which owned 40 percent of Gazprom—the Russian state gas company that controls over 95 percent of natural gas production—and is the largest earner of foreign exchange for Russia, agreed to sell part of its stake to foreign investors. On December 21, 1998, Russia's Interfax news agency announced that Ruhrgas, Gazprom's biggest export customer, had won a bid for 2.5 percent of Gazprom for $660 million [1].

Reserves

As of January 1, 1999, proven world natural gas reserves,[4] as reported by *Oil & Gas Journal*, were estimated at 5,145 trillion cubic feet, 58 trillion cubic feet higher than the estimate for 1998. Most of the increase in reserves is attributed to the developing countries, with a small increase in reserves of the industrialized regions and virtually no change in the reserves of Eastern Europe and the former Soviet Union (EE/FSU). In the industrialized regions, the decrease of 12 trillion cubic feet between 1998 and 1999 in Western Europe's natural gas reserves was offset by the doubling of Australia's reserves (from 19 to 45 trillion cubic feet) in industrialized Asia. In the developing countries, reserves in Central and South America declined by 3 trillion cubic feet between 1998 and 1999, but in every other region of the developing world, reserves increased. Proven reserve estimates increased by 13 trillion cubic feet for Africa, by 16 trillion cubic feet for Asia, and by 24 trillion cubic feet for the Middle East.

About 72 percent of the world's natural gas reserves are located in the FSU and countries of the Middle East. Russia and Iran alone account for almost one-half of the world's gas reserves (Table 11). In the industrialized world, reserves have remained fairly stable over the past 20 years. Reserves of the industrialized countries declined every year between 1993 and 1998, but in 1999 they increased by 10 trillion cubic feet because of the addition of 24 trillion cubic feet in Australia's proven reserves (Figure 32). Reserves in the EE/FSU and the developing world have, in contrast, more than doubled over the past 24 years, although since 1994 reserves in the EE/FSU have remained flat.

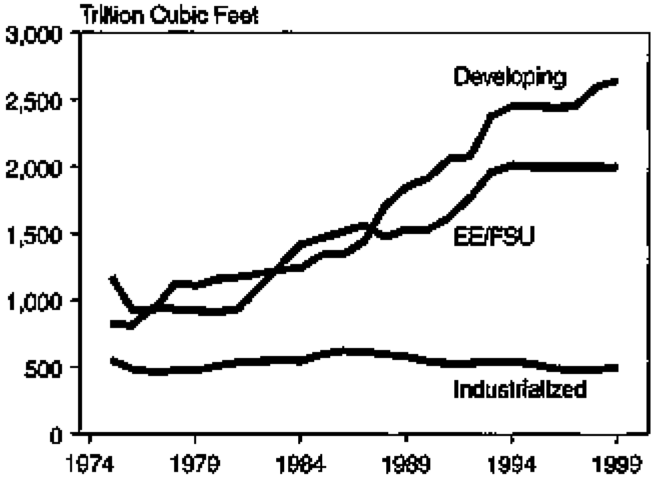
Table 11. World Natural Gas Reserves by Country as of January 1, 1999

Country	Reserves (Trillion Cubic Feet)	Percent of World Total
World	**5,145**	**100.0**
Top 20 Countries	**4,579**	**89.0**
Russian Federation	1,700	33.0
Iran	812	15.8
Qatar	300	5.8
United Arab Emirates	212	4.1
Saudi Arabia	204	4.0
United States	167	3.3
Venezuela	143	2.8
Algeria	130	2.5
Nigeria	124	2.4
Iraq	110	2.1
Turkmenistan	101	2.0
Malaysia	82	1.6
Indonesia	72	1.4
Uzbekistan	66	1.3
Kazakhstan	65	1.3
Canada	64	1.2
Mexico	63	1.2
Netherlands	63	1.2
Kuwait	52	1.0
China	48	0.9
Rest of World	**566**	**11.0**

Source: "Worldwide Look at Reserves and Production," *Oil & Gas Journal*, Vol. 96, No. 52 (December 28, 1998), pp. 38-39.

[4] Proven reserves are estimated quantities that analyses of geological and engineering data demonstrate with reasonable certainty to be recoverable in future years from known reservoirs under existing economic and operating conditions. However, significant reserves in the probable category are included in "reserves" estimates for various countries, including those of the former Soviet Union.

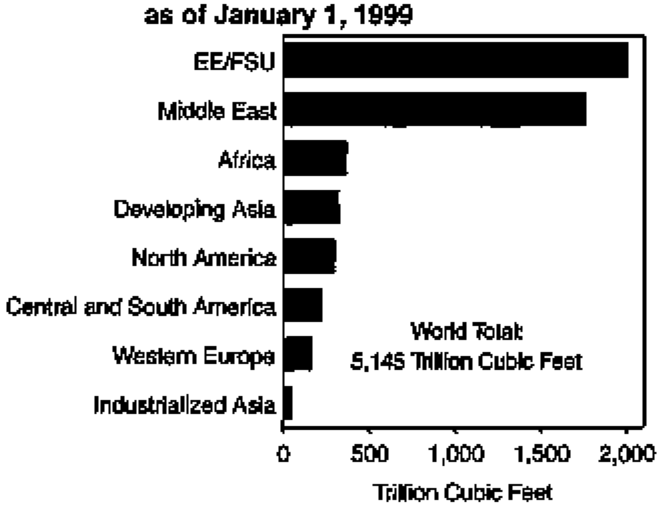
Figure 32. World Natural Gas Reserves by Region, 1975-1999



Sources: 1975-1993: "Worldwide Oil and Gas at a Glance," *International Petroleum Encyclopedia* (Tulsa, OK: PennWell Publishing, various issues). 1994-1999: *Oil & Gas Journal* (various issues).

Worldwide, natural gas reserves are more widespread geographically than oil reserves. Outside the EE/FSU and the Middle East, reserves are fairly evenly distributed, except for industrialized Asia (Figure 33). Moreover, despite high rates of increase in gas consumption, particularly over the past decade, most regional reserves-to-production ratios have remained high. Worldwide, the reserves-to-production ratio is estimated at 64.1 years [2, p. 20]. Central and South America has a reserves-to-production ration of about 72.7 years, the FSU about 86.2 years, and the Middle East and Africa both more than 100 years.

Figure 33. World Natural Gas Reserves by Region as of January 1, 1999



Source: *Oil & Gas Journal*, Vol. 96, No. 52 (December 28, 1998), pp. 38-39.

Regional Activity

North America

IEO99 projects considerable growth in natural gas markets in North America over the forecast period, with consumption increasing at an average annual rate of 1.7 percent per year. Consumption in the United States and Canada is expected to increase at rates of 1.6 and 1.7 percent per year, respectively, and consumption in Mexico is projected to increase by 3.8 percent per year. A significant portion of the growth in all three countries is expected to fuel electric power generation. The Canadian Gas Association projects that natural gas consumption for electric power generation in Canada will more than double between 1997 and 2010. The Energy Information Administration (EIA), in its *Annual Energy Outlook 1999* (*AEO99*) [3], forecasts that natural gas consumption for electric power generation in the United States will also more than double over the same period, and the Comission Reguladora De Energia (CRE) expects overall Mexican natural gas demand to more than double, with approximately half the gas used to generate electricity.

Trade among the North American countries, especially between the United States and Canada, is projected to increase considerably. According to the *AEO99* forecast, natural gas imports from Canada increase by 72 percent between 1996 and 2020, rising from 2.9 to 5.0 trillion cubic feet. Imports from Canada have until recently been constrained by pipeline capacity, and the expected increase in imports between 1996 and 2001—over 20 percent—is made possible by considerable new pipeline capacity coming on line during the period. While most of the new capacity provides access to supplies from Western Canada, where most of Canada's approximately 65 trillion cubic feet of reserves are located, new capacity is also expected to provide access to Sable Island supplies in the offshore Atlantic. Gas fields with more than 3 trillion cubic feet of total reserves are located in the Sable Island area, and considerably more reserves are thought to lie in this offshore Atlantic region.

Several projects are currently proposed to increase import capacity from Canada into the United States, and although it is unlikely that all of the proposed projects will be built, EIA assumes that some combination of those projects will add approximately 2 billion cubic feet per day of pipeline capacity to access supplies in western Canadian and 0.4 billion cubic feet per day to access Sable Island supplies. Major projects include the Alliance project, which would bring gas from British Columbia to Chicago; the Northern Border expansion, which would extend the current system (which enters the United States at the Montana border) to Indiana and possibly to the Michigan-Canada border; and the Maritimes and Northeast project, which would move supplies from Sable Island into the Northeast United States [4].

Mexico serves predominantly as an export market for U.S. natural gas. Exports from the United States to Mexico are projected in *AEO99* to grow more than sixfold between 1996 and 2020, from 0.03 to 0.19 trillion cubic feet per year. Although Mexico is rich in natural gas resources, most are located in southeastern Mexico, far from the primary consuming areas in the north and central regions of the country, and Mexico lacks the infrastructure to move the gas from the southern producing regions to the north. Consequently, it will likely be more expedient, at least for the near term, to satisfy increasing demand at least in part with imports from the United States.

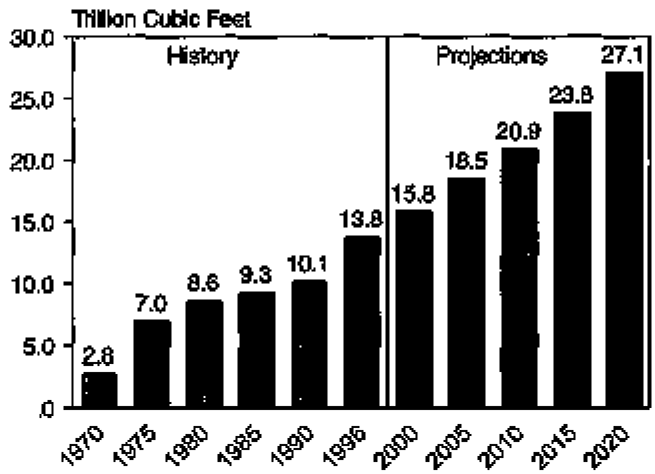
Several projects have been proposed to increase capacity to flow gas from the United States to Mexico in anticipation of the increased demand for industrial use and electric power generation in northern Mexico. If completed, the proposed projects would more than double the current U.S. export capacity to Mexico. Export capacity from Mexico to the United States has not increased over the past several years, and no new projects have been proposed. The only indication of increased exports from Mexico to the United States is Pemex's intention to export part of any increased production from the Burgos Basin in northeastern Mexico to the United States. Because of the favorable location of the Burgos Basin, Pemex plans to spend $5.5 billion over the next 15 years to increase Burgos production from 500 million cubic feet per day to 1,400 million cubic feet per day in 2001.

Mexico is making rapid progress with its plans to privatize natural gas distribution. The effort began in May 1995 with legislation that opened natural gas transmission, distribution, and storage to private investment and allowed private companies to import and export natural gas. Considerable expansion of the existing infrastructure is needed both to provide gas to fuel electricity generation and to provide access to the residential market, and much of the expansion will be accomplished by the private sector. Several distributorships have already been privatized, and Hector Olea, president of the Comision Reguladora de Energia, has indicated that 80 of the largest municipalities in Mexico will have residential gas service within 2 years. Four years ago, when the current administration came into power, only 10 to 15 cities had natural gas service [5].

Western Europe

In Western Europe, the *IEO99* reference case projects increases in natural gas demand of 2.9 percent per year over the 24-year projection period, as compared with growth of 1.7 percent per year in North America and 2.2 percent per year in industrialized Asia. Total natural gas consumption in Western Europe is projected to reach 27 trillion cubic feet by 2020 (Figure 34). The fastest regional growth is expected in "other Europe," where countries with less mature but rapidly expanding infrastructure, such as Greece, Spain, and Portugal, are included in the *IEO99* forecast.

Figure 34. Natural Gas Consumption in Western Europe, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

Several factors favor increased reliance on natural gas in Europe. Most important is access to abundant low-cost reserves. Although little new productive capability is available within continental Europe, abundant reserves are available for import from the North Sea, North Africa, and the FSU. Great strides continue to be made to install infrastructure to tap these reserves (see box on page 41). In 1998, new pipeline links to the United Kingdom and Norwegian North Sea production became operational. One link—the UK-Belgium Interconnector—is designed to allow gas to flow to continental Europe or toward the United Kingdom, depending on short-run weather-related needs. These new links add to existing capability to bring natural gas into Europe not only from the North Sea but also from Russia, Algeria, and Libya. Supplementing these developments are a variety of interconnections within continental Europe that allow gas to flow throughout

Europe's New Natural Gas Pipelines

Five major European pipelines began operating commercially in October 1998, representing some $2.7 billion in investment [6]:

- NorFra, commissioned in August 1998, is the world's longest subsea pipeline. The $1 billion NorFra is the first direct link between Norway and France that does not cross a third country. The pipeline is 521 miles long and has a capacity of 530 billion cubic feet per year, all of which is under contract. NorFra is expected to provide up to one-third of the gas requirements projected by Gaz de France. Any excess capacity will be provided to Spain and Italy after 2000.
- Artere des Hauts-de-France, Gaz de France's $185 million, on-land extension of the NorFra pipeline—with a diameter of 44 inches, the largest high-pressure pipeline ever laid in France—was also commissioned in August 1998. The pipeline, which runs from the Norwegian gas landfall near Dunkirk via the NorFra underwater pipeline to just north of Paris [7], is 115 miles long and has a capacity of 530 billion cubic feet per year, all of which has been contracted.
- The UK-Belgium Interconnector, commissioned in September 1998, runs from Bacton in the United Kingdom to Zeebrugge, Belgium. The pipeline, constructed at a cost of $745 million, has a capacity of 706 billion cubic feet per year, as well as a reverse flow capacity of 300 billion cubic feet per year (see Table 12 for committed capacity).
- Distrigas's new VTN-RTR transit network runs across Belgium. The 180-mile, $355 million pipeline was commissioned in September 1998. It has a capacity of 706 billion cubic feet per year, of which 530 billion cubic feet is under contract.
- Wingas's Wedal pipeline, commissioned in October 1998, runs from Bielefield to Aachen, nearly 200 miles across western Germany. It cost $370 million to construct, with a capacity of 388 billion cubic feet per year.

the continent. Norwegian, Russian, and Algerian gas can now be delivered to Italy, Spain, Austria, and Germany.

Various Eastern European and Balkan countries are gaining increasing access to larger and more diversified sources of gas. Strengthening European Union institutions are further contributing to growing natural gas use. In 1997, the European Union announced its natural gas directive, which is designed to enhance competition in natural gas markets. The directive seeks to free up access to pipeline transmission to enable more open dealing between natural gas consumers and suppliers. As a consequence, established pipeline companies are developing more diversified relationships with their customers and suppliers and unbundling, to varying degrees, the provision of transportation from other natural gas services. At this point, the process of regulating reform is incomplete and uneven across the region, but growing market opportunities combined with institutional pressure for change are causing revisions in established regulatory frameworks and methods of doing business.

The United Kingdom's Interconnector pipeline, between Bacton, England, and Zeebrugge, Belgium, was completed on schedule. Gas began to flow through the Interconnector on October 1, 1998 (Table 12). The line was originally estimated to cost $762 million, but actual costs were 10 percent under budget. With a glut of new gas supplies available to European countries following a mild winter, natural gas prices fell substantially in Europe in 1998. As a result, it is likely that the Interconnector will be used to ship gas to the United Kingdom should there be a surplus of continental gas over the 1999 winter season [8]. This is an interesting reversal from the situation in 1997, when the Interconnector was expected to help alleviate Britain's gas supply bubble.

The Interconnector links the United Kingdom's gas transmission system with continental gas grids. It has the capability of exporting up to 706 billion cubic feet per year of natural gas to European customers. The line can be reversed to import 300 billion cubic feet per year into the United Kingdom, and increased compression capacity would make it possible for Britain to import even more.

Gas-fired electricity generation has grown rapidly in the United Kingdom in recent years. Indeed, between 1996 and 1997, natural gas generation grew by almost one-third, replacing coal- and oil-fired plants that were taken out of service or retired [9, p. 264]. In *IEO99*, total natural gas consumption is projected to nearly double between 1996 and 2020, and gas use for electricity generation increases fourfold over that same time period (Figure 35).

Although the British government approved the construction of five additional gas-fired power plants between May and December 1997, a moratorium on new gas plant construction was issued in December in response to concerns over what the so-called "dash for gas" was doing to the British coal industry [9, p. 264]. The government has also noted that it is concerned that the rush to increase gas-fired generation at the expense of coal would lead to an over-dependence on a single energy source, stifling market competition.

Table 12. Announced Gas Sales Through the Interconnector as of October 1998

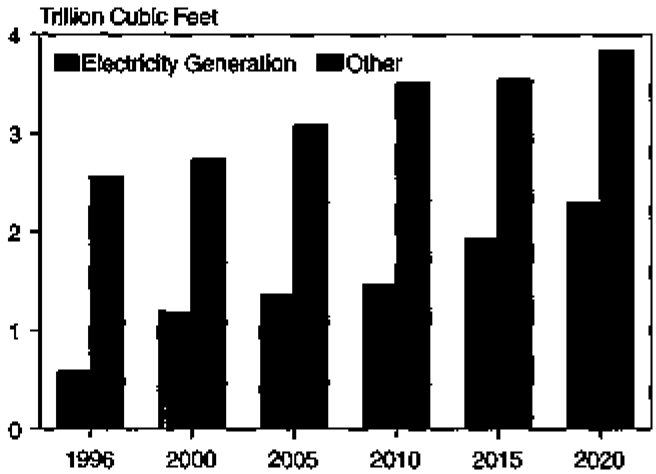
Contract Arrangement	Contract Size (Billion Cubic Feet per Year)	Supply Destination	Length of Contract (Years)
Conoco to Wingas	35	Germany	10
BG plc to Wingas	70	Germany	10
BP to Ruhrgas	35	Germany	15
Centrica to Thyssengas	18	Germany	7
Mobil to Norsk Hydro	28	Netherlands	15
Centrica to Elsta	35	Netherlands	8
Centrica to EnTrade/Delta	25	Netherlands	8
Conoco to Gasunie[a]	35	Netherlands	8.5

[a]Starts on April 1, 1999.

Note: Table excludes supply of at least 109 billion cubic feet per year by Elf from its share of the UK Elgin/Franklin field to a downstream Elf/Gaz de France co-venture yet to be established.

Source: "UK Interconnector Ushers in New Era for European Gas," *World Gas Intelligence*, Vol. 37, No. 41 (October 13, 1998).

Figure 35. Natural Gas Consumption in the United Kingdom, 1996-2020



Sources: **1996:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

A shift toward gas is still expected, despite the release of a government white paper which concluded that the comparative costs of new gas-fired stations versus coal-fired power plants did not justify the scale and speed of the dash for gas. Gas-fired projects that already have full government consent may proceed. Officials indicate that, as a result, 9,000 megawatts of such generating capacity can be built in the next 3 years, adding an extra 584 billion cubic feet per year of gas demand in the United Kingdom by 2002 [10]. This increment would allow the gas share of power generation in the United Kingdom to grow to 48 percent and reduce the coal share to 20 percent, as compared with the 1997 mix of 27 percent for gas and 38 percent for coal.

In France, natural gas consumption is expected to grow from 1.3 trillion cubic feet in 1996 to 3.0 trillion cubic feet in 2020 according to the *IEO99* reference case projections. The bulk of gas use is currently in the residential and industrial sectors, and it is expected to remain there throughout the projection period, notwithstanding the growth in natural gas use for electricity generation [9, p. 116]. Natural gas penetration into the electric utility sector is expected to increase the current gas share from less than 1 percent to more than 9 percent by 2020. The main fuel for power generation in France is nuclear power, which is projected to maintain its dominant share in the coming decades.

Two major gas pipelines to serve France were completed in 1998. First, the NorFra pipeline began operating in October 1998, bringing gas from Norway's Draupner E platform (in the Norwegian North Sea) to Loon-Plage (in the western harbor of Dunkirk, France). The 520-mile pipeline cost nearly $1 billion to complete (including costs for converting the platform, installing the pipeline, and installing the receiving facilities at Dunkirk). The line is owned by a consortium of Statoil, Norsk Hydro, Shell, Esso, Elf, Saga, Conoco, Total, Neste, Mobil, and Agip. It is the world's longest subsea pipeline and will supply France with some 530 billion cubic feet of gas per year by 2005. Spare capacity from the NorFra will be used to ship Norwegian gas to Italy beginning in 2000 [11]. Gaz de France is building a new transit pipeline across France named the "Marches du Nord-Est" for the Norway-Italy gas transmission. Norway signed a 25-year contract with Italy in 1997 for the supply of 212 billion cubic feet of natural gas per year beginning in 2000.

The second major pipeline project completed in France was the 115-mile Artere des Hauts-de-France pipeline, which links the NorFra terminal at Dunkirk to the French pipeline system near the Gournay-sur-Aronde storage facility in Oise, north of Paris. Costing about $178 million, it is the largest high-pressure pipeline in France. The existing French pipeline system now allows gas to transit from Norway to Spain, as well as accommodating imports from the Netherlands and Russia transiting through Germany, Austria, and Belgium [2, p. 28; 12, p. IV.16].

Gas consumption in Germany is expected to grow from 3.7 to 7.5 trillion cubic feet between 1996 and 2020 in the *IEO99* reference case. Since Germany's reunification in 1989, natural gas use has grown fairly quickly, as West Germany developed East Germany's gas infrastructure and converted brown coal district heating plants to run on gas [9, p. 149].

The new German government of Social Democrats (SPD) and Greens took office in October 1998 and stated its intent to dismantle the country's nuclear power industry by 2002 [13]. The new government is interested in increasing Germany's reliance on renewable energy sources, although wind power and hydroelectricity provided only 0.5 percent of Germany's 1997 primary energy requirements. Gas-fired capacity may increase as well, inasmuch as it will be difficult for the country to absorb the entire 30-percent nuclear share of electricity generation by 2002. On the other hand, the government has also proposed higher fossil fuel taxes for both electricity generation and the energy market at large, including a new tax on electricity generated from fossil fuels at 2 pfennigs per kilowatthour ($3.57 per million Btu). Taxes on natural gas would increase from 0.36 pfennigs per kilowatthour to 0.68 pfennigs per kilowatthour ($1.10 per million Btu). The SPD and Greens have announced that the revenues raised by the higher energy taxes will be used to fund job creation programs. The government had not released a timetable for implementing the new tax scheme at the time this report was prepared for publication.

One of the fastest-growing markets for gas in Western Europe is Spain (Figure 36). Natural gas demand has grown strongly in this country since the commission of the Maghreb-Europe pipeline from Algeria in 1996. According to the International Energy Agency, natural gas consumption expanded by 28 percent between 1996 and 1997 [12, p. III.300]. Spain has announced plans to install 10 gigawatts of combined-cycle gas turbine electric power plants (scaled back from an original 14 gigawatts, because the country already has excess generating capacity) [14].

In September 1998, Spain enacted its new Hydrocarbons Law, which will liberalize the country's gas markets by 2013 [15]. The Hydrocarbons Law expands on three natural gas decrees issued by Spain's Ministry of Industry and Energy over the past 2 years [16]. It supplies third-party access to the existing Spanish gas infrastructure, allowing all electricity generators, industrial users, and cogeneration plants of more than 876 million cubic feet per year to negotiate for access to LNG terminals, storage facilities, high-pressure pipelines that belong to the national gas grid, and international gas connectors. The new law will allow industrial users of more than 530 million cubic feet per year to switch from supplier Enagas beginning in 2000; by 2003 it will allow industrial users of more than 144 million cubic feet per year to switch suppliers. Only the United Kingdom has a more liberalized gas market in Europe.

Another European country that is only now beginning to develop its natural gas infrastructure is Portugal. The country began consuming natural gas in 1997, when gas supplied by Algeria through the Maghreb-Europe pipeline became available for import through Spain. Now, Transgas-Sociedade Portuguesa de Gas Natural has proposed the construction of an LNG terminal in Peniche, Setubal, or Sines [17]. No timetable has been set for a decision on the location of the LNG terminal, but Transgas has a 22-year supply agreement with Nigerian LNG for 12.4 billion cubic feet per year, beginning in 1999. Abu Dhabi and Trinidad are also considered potential LNG suppliers.

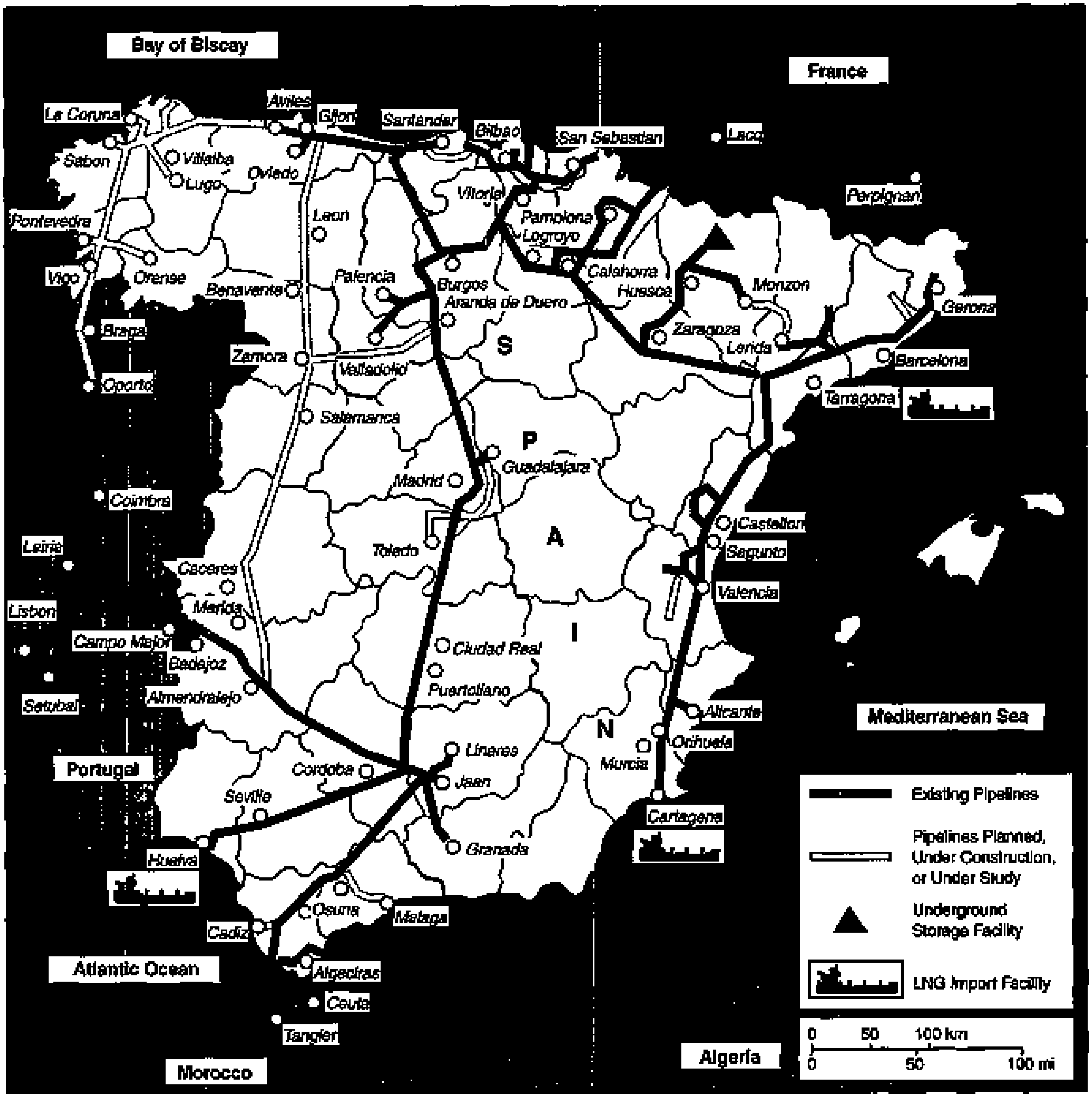
Eastern Europe and the Former Soviet Union

Although 1996 saw a reversal of the downward trend in natural gas markets in much of the EE/FSU region, markets in 1997 once again moved into decline. All but the Eastern European countries Poland and Slovakia showed decreases in consumption. Overall consumption in the FSU, which accounted for 22.4 percent of the world's total consumption of natural gas in 1997, fell by 6.4 percent from 1996 levels [2].

Several FSU countries, including Turkmenistan, Ukraine, and Kazakhstan, are projecting GDP gains for 1998 and show evidence of being on the road to economic recovery. Russia, however, is in a state of financial, economic, and political turmoil. Inflation is increasing dramatically, and efforts to maintain a stable ruble have been abandoned as of August 17, 1998. The crisis is due in part to spillover effects of the East Asian economic crisis, which has curtailed the availability and raised the cost of foreign borrowing, and in part to the sharp decline in oil and gas prices. Russia, the world's largest exporter of natural gas and second largest exporter of oil, depends heavily on oil and gas export revenues.

Gazprom, the Russian state gas company, controls more than 95 percent of Russia's natural gas production and is its largest taxpayer and hard currency earner. Because it has had difficulty making its tax payments due to nonpayment for supplies received by many of its customers, both domestic and foreign, Gazprom has resorted to curtailment of supplies in some instances and to barter in other instances in attempts to step up reduction in debts owed to the company. Bulk foodstuffs and participation

Figure 36. Spain's Natural Gas Pipeline Infrastructure, 1998



Source: International Energy Agency, *Natural Gas Information 1997* (Paris, France, 1998), p. IV.45.

in the development of the portion of the Yamal-Europe pipeline crossing Belarus have been offered by Belarus in exchange for natural gas supplies. Food, steel pipes, and oil and gas equipment have been provided by Ukraine to clear debts owed for natural gas. Goods and services, along with participation in the construction of the section of the Yamal-Europe pipeline that will pass through Poland, have been pledged to Gazprom by Poland to satisfy debts. Moldova has agreed to give Gazprom a 50-percent stake in its gas distribution network to clear part of its debt. Construction services have been agreed upon by Bulgaria to pay for part of the natural gas supplies it receives. The Russian government has prevented Gazprom from curtailing supplies to domestic users, and in August 1998 Gazprom agreed to begin making payments to reduce its tax debt in exchange for government pressure on domestic debtors to pay their gas bills.

The Russian government, which holds 40 percent of Gazprom stock, in August offered to sell 5 percent of its stake. Initially, the instability of Russian financial markets made the purchase unattractive to investors, and there were no takers. The government subsequently agreed to sell shares in blocks of 2.5 percent. Potential bidders included the German utility Ruhrgas, Royal Dutch/Shell, and Italy's Eni. Interfax news agency announced on December 21, 1998, that Ruhrgas—currently Gazprom's biggest export customer—had won the Gazprom stake for $660 million, $9 million above the Russian government's minimum requirement [1]. Gazprom itself has the option of selling another 7 percent of its own shares to foreign investors but is waiting for an upturn of the stock market to do so [18].

Russia is not alone among the FSU countries in being plagued by nonpayment for gas supplies. Uzbekistan cut off exports to Kazakhstan in 1996 for nonpayment, and Kazakhstan in return agreed to pay off its debt with Kazakh goods and with services such as transporting Uzbek products through Kazakhstan to other markets [19]. Turkmenistan, once the second largest gas producer in the FSU, dropped its output by more than 50 percent in 1997 as a result of curtailment of gas deliveries to countries, such as Ukraine, that were behind in payments. Turkmenistan's natural gas exports declined by 70 percent from 1996 levels, and it has fallen in position to fourth place in production in the FSU, behind Russia, Uzbekistan, and Ukraine. In February 1998, Turkmenistan entered into an agreement with Ukraine to supply gas through 2005, with barter for goods such as food and oil and gas supplies accounting for up to 60 percent of the payment [20].

Considerable restructuring of the natural gas industry is also underway in EE/FSU nations. In June 1998, an agreement was signed to break Gazprom into separate production, transmission, and distribution units; to allow greater access by independent producers to the pipeline system at the same rates as Gazprom's marketing unit; and to revise pipeline tariffs. The measures are to be introduced by July 1999 [21]. In August 1998 the Ukrainian government approved a plan to break up Urgazprom into three separate companies dealing with the production, transportation, and sale of natural gas [20]. In Azerbaijan, there is talk of restructuring Azerigas as part of Azerbaijan's goal to reduce imports significantly and become self-sufficient in natural gas.

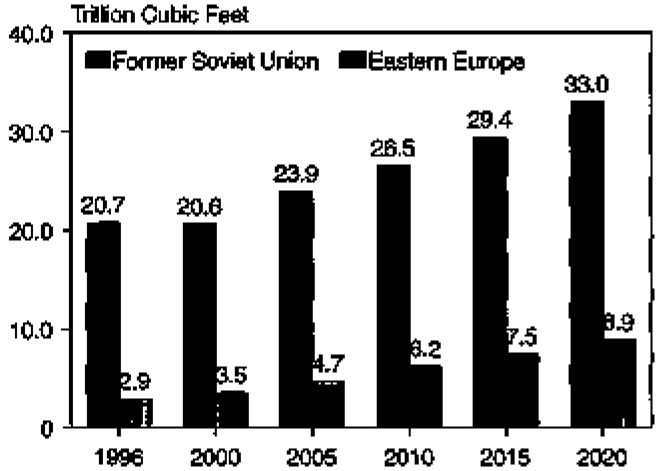
Foreign investment will be a critical component in the development of the natural gas industry in many of the EE/FSU countries. In addition to augmenting existing infrastructure, most countries need also to refurbish aging pipes and rehabilitate existing storage and production facilities. Shell is exploring a possible joint venture with Romgas, the Romanian state gas company, to rejuvenate gas fields where production has declined, to expand the gas distribution network, and to increase gas storage capacity. As a result, Romania would be able to increase revenues for the transport of Russian gas to markets in the Balkans and Eastern Europe, and to reduce its dependence on Gazprom for its own internal consumption needs [22].

Ukraine also hopes to reduce its dependence on natural gas imports by developing more of its own resources with the help of foreign investment. EuroGas, Inc., has agreed to develop coalbed methane resources in eastern and southwestern Ukraine; British Petroleum (BP) is looking into a joint venture to develop Ukrainian gas reserves; and Royal Dutch/Shell is evaluating the modernization of the country's pipeline infrastructure [20]. In Azerbaijan, legislation has been proposed to include foreign investment in the revamping of the country's natural gas industry.

Significant foreign investment has been made in the Yamal-Europe pipeline, which is Russia's primary infrastructure expansion project. Exports to Europe in the next decade are expected to increase significantly with the development of this project. Critics of the project, such as the World Bank, maintain that it is not economically sound in light of cheaper gas supplies available elsewhere, but Russia has too much invested to date to entertain thoughts of not proceeding. Other efforts include a feasibility study that Exxon and Japan Exploration Company are undertaking on a pipeline to move Russian gas from the Sakhalin I pipeline to Tokyo and the Blue Stream export pipeline, which would carry Russian supplies under the Black Sea to Turkey. Although the Yamal project is by far the most significant of the projects proposed or underway, the Blue Stream project could have considerable impact.

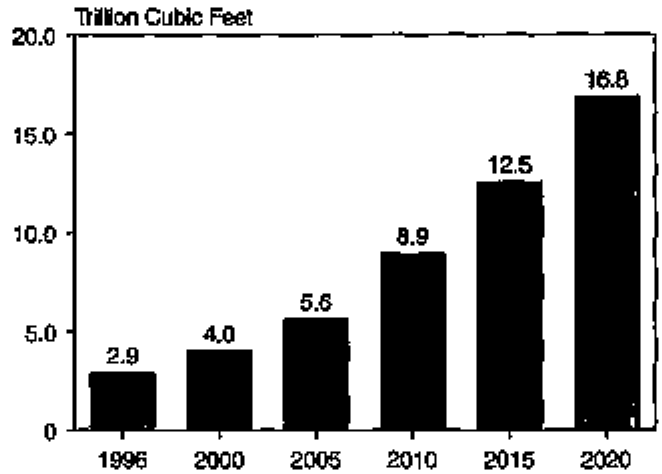
In spite of some uncertainty regarding future developments in the region, *IEO99* anticipates an eventual reversal of the overall downward trend in EE/FSU natural gas markets. Although consumption in the FSU is projected to remain level between 1996 and 2000, steady growth is expected after 2000, resulting in overall growth of 2.0 percent per year from 1996 to 2020 (Figure 37). Much higher growth is projected for Eastern Europe, where consumption is projected to grow steadily from 1996 and more than triple by 2020. The considerable foreign investment interest seen in developing the natural gas infrastructure of these countries will be a significant factor in increasing future consumption potential and export capabilities.

Figure 37. Natural Gas Consumption in the EE/FSU Region, 1996-2020



Sources: **1996:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

Figure 38. Natural Gas Consumption in Central and South America, 1996-2020



Sources: **1996:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

Central and South America

Development of the natural gas markets in Central and South America remained strong throughout 1998. Much progress was made in installing the infrastructure needed to develop the region's natural gas industry. Several pipelines connecting Argentina and Uruguay, Brazil, and Chile were completed, as well as a number of gas-fired electricity generation plants. In the *IEO99* reference case, gas use increases by 7.6 percent per year in the region between 1996 and 2020, increasing nearly sixfold over the projection period (Figure 38). Indeed, the gas share of total energy consumption increases from 18 percent in 1996 to almost 38 percent by 2020, supplying fuel for electricity generation as well as industrial, residential, and commercial consumers.

In Argentina, total natural gas consumption has increased by nearly 81 percent over the past decade [23, p. 37]. At the same time, the liberalization of energy markets in South America as a whole has given Argentina an opportunity to supply growing gas demand in Brazil, Chile, and Uruguay. Several major pipelines are now operating or are under construction to integrate this broader market framework.

There are two major pipelines under construction from Argentina to Brazil. The 273-mile Paraná-Uruguayana pipeline has a capacity of 88.3 cubic feet per day and will provide gas to a 500-megawatt thermal unit in Uruguayana by the end of 1998. The Gasoducto Mercosur will extend for 3,100 miles along the Santa Cruz de la Sierra-San Jorge Pablo pipeline.

Two major pipelines are already operating between Argentina and Chile: the 31-mile, 70.6 million cubic feet per day San Sebastián-Baudurria and the 283-mile, 177 million cubic feet per day Gas Andes pipeline, which extends from Mendoza, Argentina, to Santiago, Chile. There are future plans to increase capacity in the San Sebastián-Baudurria pipeline to 177 million cubic feet per day by the end of 1999.

There are also several pipelines under construction between Argentina and Chile. The Atacama pipeline is currently under construction and is expected to be used to fuel gas-fired electricity generators in Chile. It extends for 584 miles from northern Argentina to northern Chile and is being built by a consortium of Endesa, CMS, and YPF. The Norandino Pipeline also connects Argentina to Chile and is expected to compete with Atacama. Norandino is 544 miles long and will link the cities of Salta, Argentina, and Tocopilla, Chile. It is being built by a consortium of Tractabel, Edelnor, Electroandina, and Techint. Finally, there are plans to build the 329-mile, 35 million cubic feet per day Gas Pacífico pipeline, which would extend from the Province of Nequén, Argentina, to Concepción, Chile.

Argentina is also in the process of establishing the infrastructure needed to supply Uruguay with natural gas. In October 1998, the first Argentina-to-Uruguay natural gas pipeline was inaugurated at a cement plant of the Ancap oil company in Paysandu [24]. The 12-mile gas duct starts near the city of Colon in Argentina's Entre Rios province and leads to Paysandu. The $10 million (US) pipeline will provide gas mainly for the cement plant and, in the future, for residential use in the northern provinces of Uruguay. Several other projects are planned to link Uruguay and Argentina. The first is the 130-mile, $130 million Buenos Aires-to-Montevideo gas line (being developed by Pan-Am and British Gas), on which construction will begin early in 1999. Another is the Entre Rios-to-Casablanca line, which Ancap plans to build with a state-owned Uruguayan electricity company for a planned electric power plant in Casablanca. In addition, the 292-mile, 88 million cubic feet per day Paraná-Paysandú pipeline is being constructed by Uruguay's UTE and ANCAP.

In Brazil, total demand for natural gas grew by 10.2 percent in 1997, driven by higher consumption in the industrial and power generation sectors, which increased their demand for natural gas by 12.1 percent and 7.8 percent, respectively [23, pp. 64-65]. Most of the developments in Brazil's gas supplies focus on international contracts that bring gas from Argentina and Bolivia through several pipelines. In 1998, construction of the 1,973-mile, 285 million cubic feet per day Bolivia-to-Brazil pipeline began. The first portion of the Bolivia-to-Brazil pipeline—which will ultimately transport gas from the Río Grande Natural Gas Plant located southeast of Santa Cruz de la Sierra, Bolivia, to Guarema, Brazil—was completed at the end of 1998, and Bolivian gas sales to Brazil are scheduled to begin in the first quarter of 1999 [25, 26]. The second portion, which will extend the line from Guarema to Porto Alegre in Brazil's Rio Grande do Sul state, is expected to be in place by the end of 1999 [27].

In southern Brazil, authorities are trying to accelerate the construction of another pipeline that will connect gas reserves from Parana, Argentina, to Uruguayana, Brazil [23, pp. 64-65]. Natural gas from this pipeline will be used for a 450-megawatt gas-fired electric power plant being developed by AES Energy. In addition, state-owned energy company Petroleo Brasileiro (Petrobras) continues to develop its Natural Gas Project of Urucu, which will allow the distribution system to transport gas to Porto Velho for additional gas-fired electricity generation units.

There is movement to bring LNG to Brazil. In November 1998, Petrobras and Royal Dutch/Shell Group formed a joint venture to develop a regasification terminal about 20 miles south of Recife at Suape port in Pernambuco state. It will be South American's first LNG regasification terminal [28]. The $200 million terminal is scheduled for completion by 2003 with an annual capacity of 1.5 million metric tons. Shell and Petrobras are looking to Trinidad and Tobago and Nigeria LNG projects for potential supplies.

Much of the increase in Brazil's natural gas consumption will be used to fuel gas-fired electricity generation. According to the Sao Paulo state government, gas demand for power generation is expected to grow from virtually nothing at the present to more than 500 million cubic feet per day by 2003, accounting for all of the "more than 1 billion cubic feet per day in shipments slated to reach Sao Paulo" [29]. Many plants are either under construction or in the planning stages. AES Corp recently began constructing a 600-megawatt gas-fired plant at Uruguaiana in Brazil's Rio Grande do Sul state [30]. The $250 million plant should be completed by the end of 2000, using gas imported from Argentina through a 273-mile pipeline currently under construction. Construction of a $400 million, 800-megawatt gas-fired plant near Sao Paulo, Brazil, by Entergy Power Group will begin in 2000, with completion scheduled for mid-2002 [30]. Entergy is also discussing plans for a second plant in the state of Rio de Janeiro. Brazil's Coelba is planning to build a 240-megawatt gas-fired plant in either Bahia or Rio Grande do Norte for an estimated $100 million. The company will determine where the plant will be built, based on the package of subsidies and fiscal incentives each state government is willing to offer.

In Peru, the Camisea and Aguaytía natural gas fields represent important potential sources of natural gas in South America [23, pp. 182-183]. In June 1996, Shell Exploration and Mobil Corporation signed a contract to develop the Camisea gas fields discovered by Shell in the 1980s. Estimates are that the Camisea fields contain between 11 and 20 trillion cubic feet of natural gas, which could supply Peru's needs for more than 100 years.

In addition, several nearby natural gas finds announced in 1998 strengthen the area's potential as a long-term source of natural gas from Peru. Unfortunately, the Camisea fields are remotely located—some 800 miles south of Lima—and the lack of a well-developed natural gas infrastructure has delayed the development of the reserves. Plans were to have Camisea in full production by 2010, but Shell and Mobil removed themselves from developing the estimated $3 billion project on July 15, 1998, saying they could not commit to phase 2 of the project under the government's terms. The two companies were asking the Peruvian government to increase the gas price to $2.45 per million Btu, which the government declined to do [31]. Peru now plans to tender a three-stage project for Camisea in early 1999 [32]. The tenders will include developing the Camisea fields; constructing processing facilities; building a pipeline from the fields to the coast; and organizing the gas distribution system. The Peruvian government expects to see gas deliveries to Lima begin in 2003 [33].

Development of the Camisea and Aguaytía fields has the potential of making Peru a net energy exporter by the beginning of 2000 [23, pp. 182-183]. The completion of the 155-megawatt gas-fired Aguaytía power plant in May 1998 means that Peru is now generating 7 percent of its electricity with gas. The power plant was built by Maple Companies of Dallas, Texas and PanEnergy at a cost of about $254 million.

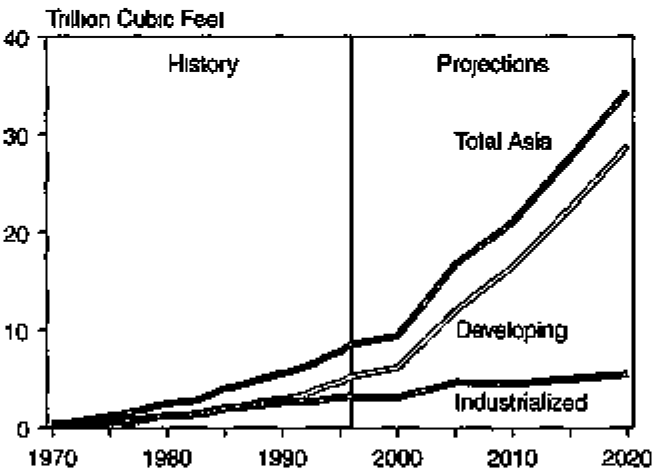
In Chile, the competition between the two Argentina-to-Chile pipeline projects, Gas Atacama (controlled by the U.S. CMS Energy and Chile's Endesa) and Norandino (controlled mostly by Belgium's Tractebel) continued in 1998. Gas Atacama has already secured 212 million cubic feet per day in contracts of its 300 million cubic feet per day capacity, mostly with its subsidiary, Nopel [34]. The state-run Chuquicamata copper mine is among the new customers it now hopes to pick up.

Power company Electroandina plans to bring its first two 400-megawatt gas-fired units into operation over the next 18 months. Along with Gas Atacama's 710-megawatt Nopel plant and a transmission line from Argentina being built by the Gener electricity company, a serious oversupply of electricity could develop in northern Chile's 1,200-megawatt grid.

Asia

Natural gas markets in Asia had mixed reactions to the Southeast Asian economic downturn that began in the spring of 1997. Many planned gas projects have been delayed or scaled back, most notably projects in hard-hit Thailand and Indonesia, although signs of gas demand growth are evident in China and India. In the *IEO99* reference case, natural gas consumption in all of Asia is expected to maintain a healthy growth rate of 5.9 percent per year over the 24-year projection period. Gas use more than triples, reaching 34 trillion cubic feet in 2020, from the 1996 level of 9 trillion cubic feet (Figure 39).

Figure 39. Natural Gas Consumption in Asia by Region, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

Industrialized Asia

Natural gas use in the countries of industrialized Asia rises from 3.3 trillion cubic feet in 1996 to 5.5 trillion cubic feet in 2020. The bulk of the increment is attributed to increases in gas demand in Japan, most of it in the form of LNG. Japan is the world's largest importer of LNG. In 1997, the country imported 58 percent of the world's LNG, some 47 million metric tons [2, p. 28]. In the short term, Japan's demand for LNG is expected to be dampened by the country's economic recession; however, several long-term plans to import LNG continued in 1998 (see box on page 49). Japan's Osaka Gas signed an agreement with Oman LNG Company for the supply of 0.7 million metric tons per year of LNG over a 25 year period beginning at the end of 2000 [35]. Last year Osaka imported 5.3 million metric tons of LNG.

There are substantial natural gas reserves in Australia. Not surprisingly, 98 percent of the industrialized Asian gas production can be attributed to this country [46]. Australia exports about one-third of the natural gas produced in the form of LNG. Most of Australia's LNG is exported to Japan, but the United States, Turkey, and Spain have also imported LNG from Australia in recent years.

Australia has plans to expand its LNG production, including proposals to develop the Gorgon LNG resources for export to China's Guangdong province, as well as a plan to build a domestic LNG plant in Western Australia to supply gas to the West Kimberley region for power generation in remote towns such as Broome and Derby and in remote mining locations [44, 45]. Both projects are still in the planning stages. China has said it is committed to building an LNG demonstration project in Guangdong, but it has not committed to purchasing LNG from Australia, which would be necessary to justify construction of the Gorgon project.

Developing Asia

Although some of the major emerging markets of developing Asia—including South Korea, Thailand, and Indonesia—are still in economic recession, natural gas developments in China and India seemed to be moving forward strongly at the end of 1998. China is poised to bring LNG to its southeastern Guangdong province and is discussing plans to pipe natural gas from Russia. Indeed, *IEO99* projects China's natural gas use to grow 14-fold from 1996 to 2020. Prospects for gas use in India are also optimistic in the *IEO99* forecast. In 1998, after several years of indecision, India's Petronet secured several supply contracts for LNG for its two LNG regasification projects, and Enron arranged LNG supplies for its Dabhol power plant.

China is becoming increasingly interested in pursuing the development of a natural gas infrastructure as it becomes more and more dependent on crude oil imports and as pollution problems resulting from heavy reliance on coal use worsen. Beijing is studying plans for several

The Status of Worldwide Liquefied Natural Gas

Low world oil prices, combined with reduced demand for natural gas to fuel electric power generation in the industrial sectors of key LNG consumers Japan and South Korea, has adversely affected LNG producers and threatened economic prospects for industry development. Both Japan and South Korea have had to cut back on the amount of LNG they planned to import. With many LNG contract prices gauged to world oil prices, LNG producers must reevaluate the economic feasibility of continuing with plans to build or expand LNG facilities.

Despite these problems, LNG exporters have, in many cases, continued to develop and expand their plants and have been able to attract new customers for their product. In particular, in the last quarter 1998 several LNG supply agreements were made for gas-fired projects in India, and China now appears ready to begin development of its first LNG regasification facility in Guangdong province.

The Asian recession has led to several delays and cutbacks in LNG supplies for Japan and South Korea. Korean Gas Company and Japan's Osaka Gas requested in 1998 that Pertamina allow them to temporarily reduce their LNG offtake [36]. Under long-term contract, Korea Gas had committed to purchasing 5.2 million metric tons of LNG per year and Osaka Gas 3.0 million metric tons per year. Even though both contracts contained take-or-pay clauses, Pertamina agreed to temporary reductions, provided both firms buy the shortfalls once demand begins to grow again. Similar arrangements were made with Petronas of Malaysia [37].

Pertamina was especially hard hit because of its high dependence on Japanese and South Korean LNG customers. The Indonesian state oil and gas company estimated that its LNG exports would decrease by more than 4 percent in 1998 because of reduced demand in Japan and South Korea [36]. In 1998, Pertamina's total LNG exports declined from 523 to 501 shipments.

Dependence on South Korea and Japan in LNG markets has posed difficulties for industry expansion programs. The debt of Qatar's RasGas—still planned for completion in 1999—was downgraded in December 1998 by the U.S. ratings agency, Moody's Investors Service [38]. Moody's cited its fear of a "damaging gas demand slowdown in the project's biggest buyer country, Korea." The agency is also concerned that the privatization of Korea's natural gas industry might adversely affect the demand for LNG, and that sustained low world oil prices to which LNG prices are tied might make it unprofitable to operate RasGas.

Japanese LNG buyers announced that they expected to take between 5 and 10 percent less LNG than their annual contracted volumes of about 54 million metric tons in 1999 [37]. The three largest Japanese utilities—Tokyo Electric (Tepco), Tokyo Gas, and Osaka Gas—currently are negotiating with Malaysia's Petronas, Indonesia's Pertamina, and other suppliers to determine how large their volume reductions for 1999 might be. Although Japan actually increased its imports between 1997 and 1998, the number of LNG cargoes it contracted with Pertamina was reduced by four.

Several planned LNG facilities are facing delays, including Australia's Darwin II and Gorgon projects and Indonesia's Tangguh, all of which were expected to begin operating in 2003 [39]. Russia's 6.0 million metric ton per year Sakhalin II, Yemen's 5.2 million metric ton facility, and Canada's 3.5 million metric ton Pac-Rim LNG may also be delayed from their original construction timetables.

Still, in the midst of the problems associated with the traditional Asian LNG markets, new markets are resulting in several new supply opportunities for LNG producers. India is proving to be a particularly good outlet for LNG exports, and the country completed several LNG supply agreements at the end of 1998. Oman LNG signed a 20-year supply and purchase agreement with Enron to supply 1.6 million metric tons of LNG to Enron's Dabhol power plant in the western Indian state of Maharastra [40]—the first LNG contract to be signed in India and the first LNG contract in Asia signed with an independent power project. In fact, with the Dabhol purchase, capacity on the Oman LNG project, which is scheduled to begin delivery in April 2000, was completely sold out, although the majority of the LNG is slated to go to South Korea's Kogas (4.1 of the total 6.4 million metric tons per year) and Japan's Osaka Gas (0.7 million metric tons) [41].

Qatar's Ras Laffan (RasGas) signed a 7.5 million metric ton per year supply contract with India's Petronet in December 1998 [37]. In September, RasGas won the Petronet tender to supply 5 million metric tons of LNG to India's Dahej, Gujarat, and 2.5 million metric tons to Cochin, Kerala [42]. In addition, India's West Bengal state is reported to have begun lobbying Petronet for a new LNG facility at Haldia.

The Yemen LNG project was scheduled to begin operating in 2001, but that completion date is likely to be delayed [42]. In May 1998, BG UK Holdings Ltd. (a subsidiary of British Gas International) and the Yemen

(continued on page 50)

The Status of Worldwide Liquefied Natural Gas (Continued)

LNG Company announced an agreement for Yemen LNG to supply 2.65 million metric tons of LNG per year (with the possibility of an increase to 5.3 million metric tons per year) for a 25-year period [43]. BG will use the LNG for its planned LNG terminal at Pipavav in India's Gujarat state. Deliveries are expected to begin some time between mid-2002 and mid-2003 [42]. Yemen LNG is also actively seeking customers in Taiwan, Turkey, and Lebanon, as well as Japan and South Korea.

In Australia, two projects may boost the country's LNG industry. One is a proposal submitted to the Western Australian government in November 1998 by Woodside Energy Ltd. and Energy Equity Corporation to build an LNG plant that would serve remote towns and mining sites in Western Australia [44]. The plant would provide natural gas to the West Kimberley region and would be used for electric power generation in towns such as Broome, Derby, and Halls Creek, as well as in remote mining sites [42]. The $70 million facility would be constructed at Port Hedland. Gas for the project would be supplied from Woodside's North West Shelf fields.

The second potential Australian project is the Gorgon LNG facility. Originally scheduled for completion in 2003, the project has been delayed largely because of problems in identifying enough potential customers [39, 45]. In October 1998, however, China and Australia announced intentions to build China's first LNG facility to serve southern China's Guangdong province [45]. The proposed demonstration project would involve an initial supply of 3 million tons of LNG and make it economically possible for Australia to move forward with its Gorgon project.

Nigeria LNG Ltd. is expected to complete its two-train Bonny Island LNG plant and begin deliveries in October 1999 [42]. Expansion of the facility would raise the LNG output from 5.9 million metric tons per year to 8.7 million metric tons per year. Long-term contracts for Bonny Island LNG have already been established with Italy's ENEL, Spain's Enegas, Turkey's Botas, and Gaz de France. The consortium members, however, are currently considering expanding Bonny Island by about 45 percent within the next 4 years.

natural gas pipeline projects with Russia. Gazprom Board Chairman Rem Vyakhirev stated that Russia planned to supply China with between 1.1 and 1.3 billion cubic feet of natural gas per year from Western Siberia [47]. The timetable for construction has not been announced.

In October 1998, China and Australia announced intentions to build China's first LNG facility to serve southern China's Guangdong province [45]. The proposed demonstration project would involve an initial supply of 3 million metric tons of LNG and make it economically possible for Australia to move forward with its Gorgon project. The experimental LNG project at Guangdong would be built near Shenzhen just north of Hong Kong. It would cost an estimated $600 million and is expected to be completed by 2005 [48]. A detailed plan of the project is to be submitted in April 1999. An estimated 80 percent of the first 3 million tons of LNG are to be used for electricity generation. After 2 to 3 years, however, another 2 million tons of capacity would be added for residential and industrial use. There are additional proposals for two other terminals: one in Fujian province (north of Guangdong) and one in Shanghai. When completed in 2010, the three plants would require up to 15 million tons of LNG.

In India, Enron arranged the supply of 1.2 million tons per year of LNG for a 20-year period from Oman LNG [49]. Supplies are expected to begin in 2001 with the completion of the 1,624-megawatt phase 2 of the company's Dabhol power plant in the western Indian state of Maharashtra (Dabhol's 826-megawatt phase 1 will be fueled initially on naphtha or distillate, but the entire project will use natural gas once phase 2 is completed). Construction of the LNG import terminal along with regasification facilities at Dabhol began at the end of 1998 [50].

When completed and operating at full capacity, the Dabhol project will need 2 million tons of LNG per year. Beyond the supplies already secured from Oman LNG, additional supply may come from Qatar, where Enron has proposed its own LNG liquefaction plant to be commissioned in 1999 near the existing Qatargas and RasGas plants.

There are also plans to build two regasification terminals in India. The joint venture Petronet (set up by Indian state firms GAIL, ONGC, IOC, and BPCL) is developing one 5 million ton per year LNG terminal at Dahej (in the western state of Gujarat) and a 2.5 million ton per year LNG terminal at Cochin (in the southern province of Kerala) [51]. Both terminals will import LNG from Mobil Corporation and Qatar's RasGas. Although final details of the supply agreement must be worked out, RasGas is expected to supply India with 7.5 million tons of LNG per year over a 20-year period [52]. First deliveries of the

LNG are expected to begin in 2002. Petronet is also considering constructing a third terminal at Mangalore, and India's Foreign Investment Board approved a proposal to construct an LNG terminal in Kakinada on the eastern coast in September 1998 [39]. British Gas International and the Yemen LNG Company signed a memorandum of understanding to begin the Pipavav LNG project in Gujarat with initial deliveries planned by mid-2003.

The success of these LNG projects will have an impact on the development of natural gas projects throughout India. Plans to develop a 1,900-megawatt gas-fired Kayamkulam stage-II project in the southern Indian state of Kerala will be carried out only if an LNG supply can be secured [53]. The success of negotiations with the Mobil and RasGas consortium of Qatar makes it more likely that the Kayamkulam stage-II will be constructed. The first 115-megawatt unit of the 350-megawatt Kayamkulam stage-I project of National Thermal Power Corporation—to be fueled by naphtha—began trial runs in November 1998.

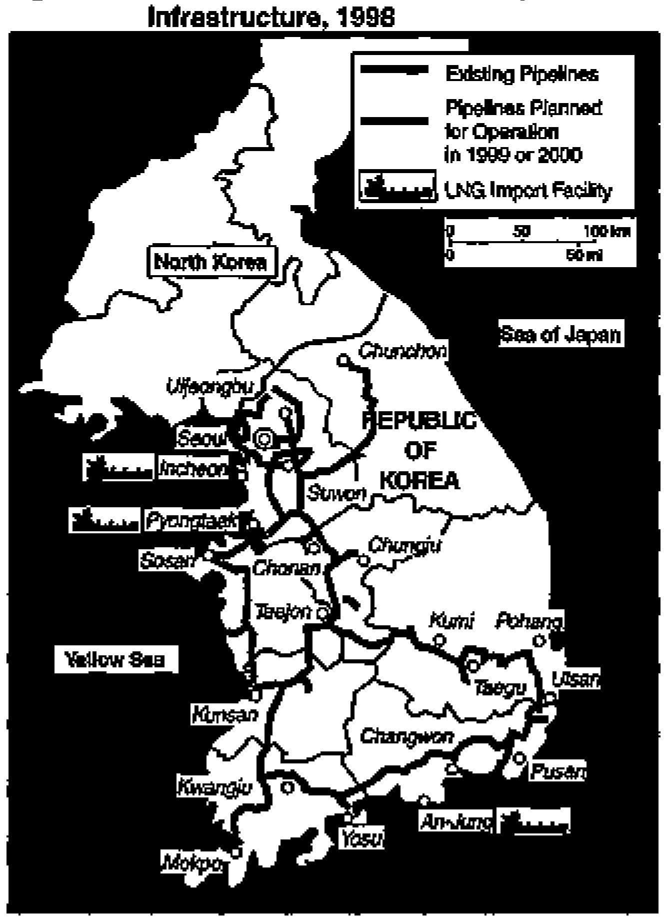
The economic troubles of Southeast Asia have had a dampening affect on natural gas development in South Korea. The state-owned gas importer and supplier, Korean Gas Corporation (Kogas), recently revised downward its projections of LNG imports from 14.16 to 12.96 million metric tons in 1999 [54]. Most of the reductions are attributed to the electric power sector. Korean Electric Power Company (Kepco), the country's electric power company, has informed Kogas it would like to reduce its planned LNG purchases for the period of 1999 to 2003 by 30 percent. As a result, Kogas has negotiated delivery delays under existing contracts and has scaled back spot market purchases.

Because Kogas is committed to purchase LNG under a number of medium- to long-term take-or-pay contracts, there is pressure to speed expansion of the country's gas transmission infrastructure so that the gas can be redirected from electricity generation to residential, commercial, and industrial uses (Figure 40). Kogas has existing contracts with Brunei, Malaysia, and Indonesia, as well as two new 25-year contracts of 4 million metric tons each with Qatar's Ras Laffan and Oman's LNG project, which are scheduled to begin in 1999 and 2000, respectively.

Natural gas from Myanmar's (formerly Burma) Yadana field started flowing to Thailand for the first time on July 30, 1998, on a trial basis—one month behind the original schedule [55]. The pipeline from the offshore field in the Gulf of Martaban to Thailand becomes the second cross-border pipeline in Asia after the Malaysia-Singapore line. In October, Thailand had to postpone commercial gas deliveries until April 1999, some 8 months behind the original schedule [56]. The Petroleum Authority of Thailand (PTT) was supposed to begin receiving Yadana gas in July 1998. However, completion of the entire 1,800 megawatt Ratchaburi plant will be between 8 and 9 months behind original schedules. PTT is trying to avoid the heavy contractual penalties under its 30-year take-or-pay contract with the Yadana consortium. Since July 30, PTT has only been able to take delivery of 5 million cubic feet per day of the 65 million cubic feet per day initial rate stipulated in the Yadana supply contract. Under the contract, PTT was committed to gradually raising its imports of Yadana gas to 525 million cubic feet per day 15 months after production began in July 1998. PTT has wanted to pay only for the amount of gas it actually receives. It was bound by the contract to also pay for undelivered gas at the end of the year.

Indeed, Thailand has had to scale back many of the projects it had undertaken prior to the economic recession that has followed the floating and then collapse of the national currency, the baht, in July 1997. The project delays are, in part, attributed to lowered gas demand than expected before the recession, but project development is also hindered by constraints on public finance imposed by agreements made with the International Monetary Fund for foreign currency loans to support

Figure 40. South Korea's Natural Gas Pipeline Infrastructure, 1998



Source: International Energy Agency, *Natural Gas Information 1997* (Paris, France, 1998), p. IV.31.

Thailand's external accounts. As a result, funding for gas infrastructure construction has been reduced substantially. PTT reduced planned expenditures by about 30 percent to $2.23 billion (U.S.) for 12 projects to be developed between 1998 and 2006 [57] (Table 13).

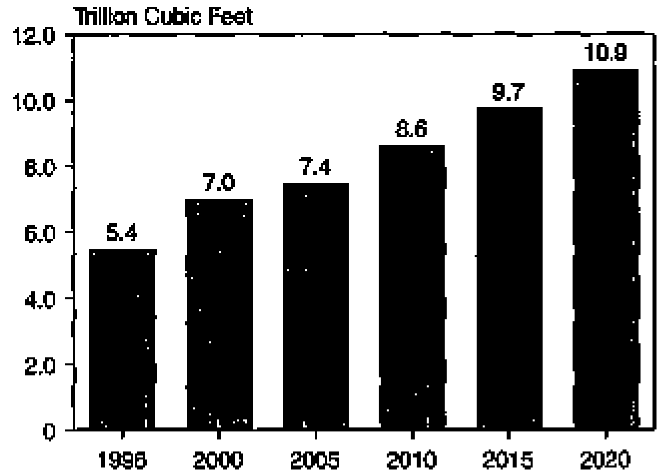
PTT has decided to postpone indefinitely a planned trunk line that was to run from Unocal's Erawan gas field in the Gulf of Thailand to Ratchaburi [58]. The trunk line was to become the third in the Gulf of Thailand and was intended to bring natural gas from new fields, particularly those in the Malaysia-Thailand Joint Development Area, an offshore area in the southern Gulf jointly administered by Malaysia and Thailand. Other projects dropped include the Pailin to Songkhla and Songkhla to Yala projects, as well as the Surat Thani to Krabi and South Bangkok projects.

Middle East

Natural gas reserves in the Middle East are second only to those in the FSU region. As of January 1, 1999, Middle East reserves accounted for 1,750 trillion cubic feet [59]. Middle Eastern gas use is expected to grow by 2.9 percent annually over the 24-year projection period, increasing from 5.4 trillion cubic feet in 1996 to 10.9 trillion cubic feet in 2020 (Figure 41). Gas is presently exported as LNG through projects in Abu Dhabi, Qatar, and Oman, but several pipeline projects have been proposed or are under development to supply gas to Asian countries such as India and Pakistan, as well as to Western European countries using Turkey as a transit.

Almost one-half of the Middle East's gas reserves (812 trillion cubic feet) are in Iran, where many natural gas projects moved ahead in 1998. In August, the National Iranian Oil Company announced that 43 oil and gas projects worth over $5 billion would be opened to international firms on a "buyback" basis [60].[5] More than 70 companies responded to the buyback offers.

Figure 41. Natural Gas Consumption in the Middle East, 1996-2020



Sources: **1996:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

A $2 billion project to develop Iran's South Pars gas and condensate field was proposed by a consortium of France's Total, Malaysia's Petronas, and Russia's Gazprom in 1997, but the project was opposed by the United States as a violation of the Iran-Libya Sanctions Act, which imposes sanctions against companies that invest more than $20 million in energy ventures in the two countries [61]. In May 1998, the United States agreed

Table 13. Petroleum Authority of Thailand Natural Gas Pipeline Plan, 1998-2006

Project	Scheduled Completion Date	Cost (Million Baht)
From Pailin Field (offshore)	1999-2000	2,460
JDA to Erawan	End of 2003	24,740
Midline compressor with platform and extension pipe	End of 2000	8,222
Rayong to Bang Pakong	End of 2000	9,331
Ratchaburi to Wang Noi	May 2000	10,660
Ratchaburi-Wang Noi to South Bangkok power plant	Construction delayed indefinitely	4,190
Joining Benjamas Field and Tantawan Field	Mid-1999	535
From Parallel Pipeline to Thap Sa Kae power plant	End of 2006	9,172
From JDA to Songkhla	End of 2000	5,729
From Songkhla to Yala (Thai-Malaysian border)	End of 2000	2,830
From Khanom gas separation plant to Surat Thani	End of 2002	2,508
From Surat Thani plant to Krabi plant	End of 2004	6,239

Source: "Thai Planning Bolstered by More Gas Reserves," *Financial Times: Asia Gas Report*, No. 15 (August 1998), p. 25; and "Economic Woes, Sagging Demand Slow Thai Gas Pipeline Projects," *Oil & Gas Journal*, Vol. 96, No. 46 (November 16, 1998), pp. 27-34.

[5]Because of Iran's constitutional ban on foreign companies owning any of its oil and gas reserves, the companies would finance the energy projects and receive resulting repayment for their investment with oil and gas production.

to waive the U.S. sanctions, and gas production from the project is expected to begin in June 2001, providing 2 billion cubic feet per day to Iran's domestic gas pipeline network [62].

Turkey has one of the fastest developing gas markets in the world. Its natural gas use has more than doubled over the past 6 years, from 122 billion cubic feet in 1990 to 277 billion cubic feet in 1996 [63]. The country has spent the past decade securing gas suppliers. In 1987, the former Soviet Union began providing natural gas through a pipeline completed in that year and running from the Bulgarian border to Istanbul and then to Ankara [64, p. 269]. In 1993, both Algeria and Qatar began supplying the country with LNG. And in 1996 Turkey signed a contract with Iran for the construction of a gas pipeline from Iran and about 88 billion cubic feet of natural gas per year beginning in 1999.

In October 1998, Turkey signed a 30-year preliminary agreement to buy natural gas from Turkmenistan by way of a 1,050-mile trans-Caspian pipeline [65]. Royal Dutch/Shell and Enron Corporation are preparing feasibility studies for exporting Turkmen gas to Turkey either through Iran or through the Caspian Sea, then crossing Azerbaijan and Georgia. The U.S. Government is opposed to a route through Iran.

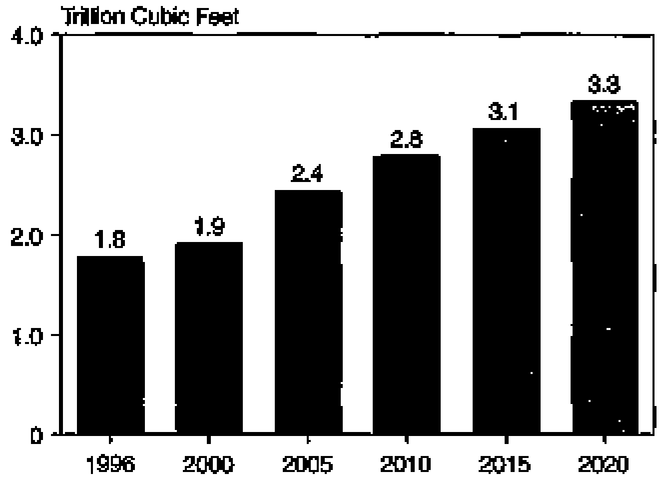
Oman LNG announced that construction of a $2 billion plant at Qalhat will begin at the end of 1999, with two trains each with a capacity of 3.3 million tons per year [35]. In addition to a contract to supply Osaka Gas with 0.7 million tons of LNG per year for a 25-year period, Oman secured a 4.1 million ton per year gas supply agreement with Korea Gas Corporation (Kogas), with deliveries scheduled to begin in April 2000, and signed an agreement to supply 1.2 million tons per year to Enron's Dabhol Power Project in western India, with options to increase the amount to 1.6 million tons per year [66]. Earlier plans to supply Thailand with LNG were canceled when Thailand's projections for energy demand fell as a result of the Southeast Asian economic recession.

Abu Dhabi is attempting to expand its gas production for use in electricity generation and for use in injection in its oil fields to increase oil recovery. CMS Energy was chosen to build Abu Dhabi's first privately owned electric power plant, the $770 million Al Taweelah A2 [64, p. 295]. Construction on the gas-fired project is scheduled to begin early in 1999, and it should be fully operational by August 2001. The emirate exports gas through its Das Island LNG project, mostly to Japanese customers, which account for over 5 million tons of LNG per year in contracts [64, p. 17]. There were plans to increase the Das Island capacity by some 200 billion cubic feet, but the Asian economic crisis makes it unlikely that the plans will go ahead in the short term.

Africa

Natural gas consumption in Africa is projected to rise from 1.8 trillion cubic feet in 1996 to 3.3 trillion cubic feet in 2020, an increase of 2.7 percent per year (Figure 42). Almost 92 percent of the continent's gas reserves are contained in only four countries: Algeria, Nigeria, Libya, and Egypt.

Figure 42. Natural Gas Consumption in Africa, 1996-2020



Sources: **1996:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

Algeria has the largest natural gas reserves in Africa, with an estimated 131 trillion cubic feet. Most of the gas produced in the country is exported to Europe through two existing pipelines: the Transmed—which runs from Algeria's Hassi R'Mel field through Tunisia to Italy—and the Maghreb-Europe—which also runs from the Hassi R'Mel field through Morocco to Spain's Seville and to Portugal. In addition to Italy and Tunisia, Algeria is able to supply natural gas to Slovenia through the Transmed pipeline [64, p. 126].

Algeria also has a substantial number of LNG export contracts worldwide. It currently supplies France, Belgium, Spain, Italy, Turkey, Greece, and the United States with varying amounts of LNG. LNG plants at Arzew, Bethioua, and Skikda have all been renovated, increasing capacity at the three plants from 1.1 to 1.2 trillion cubic feet per year.

Nigeria has an estimated 35 percent of Africa's natural gas proven reserves, about 120 trillion cubic feet [67]. At present, about 75 percent of the natural gas Nigeria produces (during oil production) is flared [64, p. 126]; however, several projects are underway to reduce the amount of flared gas, including schemes to increase domestic gas use, pipe gas to surrounding countries, export LNG to Europe and Turkey, and develop a gas-to-liquids project. The elimination of gas flaring in

Nigeria would have reduced its total carbon emissions by half, or by about 13 million metric tons, in 1996.

Royal Dutch/Shell's Shell Nigeria Limited plans to double the domestic use of natural gas within the next 5 years in Nigeria. The company plans to invest $38.7 million in local gas projects, including 68 miles of gas distribution pipelines. Shell recently signed to supply 80 million cubic feet of gas per day to Global Energy & Refining Nigeria.

Nigeria completed the first phase of its three-phase Escravos project in 1997. The $550 million project gathers and processes 165 million cubic feet of natural gas per day, all of which is consumed in Nigeria. The second phase will be for the export of 120 million cubic feet of gas per day to the West African Gas Pipeline (WAG). By the time the final phase—which is expected to capture another 300 million cubic feet per day—is completed, Nigeria will have almost entirely eliminated gas flaring.

Nigeria's Bonny LNG project is expected to go on line in 2000, and 20-year supply contracts have already been signed with Gaz de France (14 billion cubic feet per year), Spain's Enagas (56 billion cubic feet per year), and Turkey's Botas (42 billion cubic feet per year). The $4.5 billion project consists of two liquefaction trains, export infrastructure, and a gas transmission system with a capacity of 254 billion cubic feet [64, p. 126].

The proposed WAG project moved a step closer to becoming a reality in 1998 as Chevron and the state-owned Nigeria National Petroleum Corporation signed a 20-year, 14.6 billion cubic feet per year contract to supply gas to a power plant in Ghana [68]. Construction on the $200 million, 220-megawatt power plant is expected to begin early in 1999. The 625-mile WAG line is not expected to be completed before 2001, and until that time, the power plant in Ghana will be fueled with crude oil supplied by Chevron.

Chevron and South Africa's Sasol are working to develop a gas-to-liquids facility that would use some of the gas from the Escravos project's final phase. The plant would convert natural gas into middle distillates such as jet fuel, diesel, and kerosene, and into intermediate feedstocks. Chevron and Sasol estimate that they could use 200 million cubic feet of feedstock gas per day to produce 20,000 barrels of diesel and other middle distillates per day. The project is still in the planning stages, however, and no time frame has been released.

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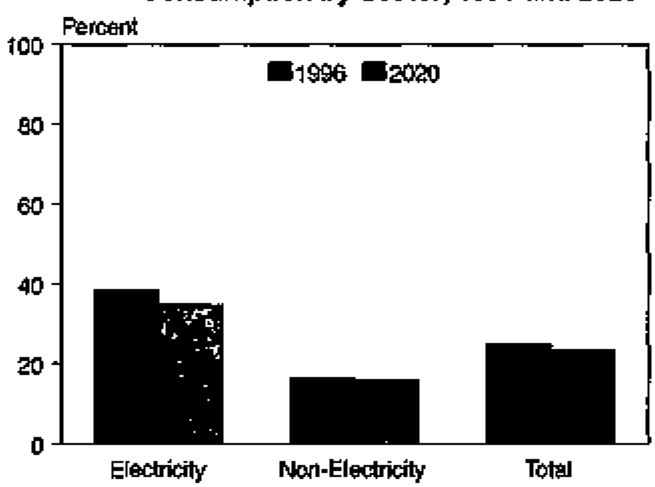
Coal

Coal's share of world energy consumption falls slightly in the IEO99 forecast. Coal continues to dominate many national fuel markets in developing Asia, but it is projected to lose market share to natural gas in some other areas of the world.

Historically, trends in coal consumption have varied considerably by region. Despite declines in some regions, world coal consumption has increased from 84 quadrillion British thermal units (Btu) in 1985 to 93 quadrillion Btu in 1996. Regions that have seen increases in coal consumption include the United States, Japan, and developing Asia. Declines have occurred in Western Europe, Eastern Europe, and the countries of the former Soviet Union. In Western Europe, coal consumption declined by 30 percent (on a Btu basis) between 1985 and 1996, displaced in considerable measure by growing use of natural gas and, in France, by nuclear power. The countries of Eastern Europe and former Soviet Union (EE/FSU) saw an even sharper decline in coal use during the period (a 39-percent decline), primarily the result of reduced economic activity.

Although coal has lost market share to petroleum products, natural gas, and nuclear power, it continues to be a key source of energy, especially for electric power generation. In 1996, coal accounted for 25 percent of the world's primary energy consumption (down from 27 percent in 1985) and 38 percent of the energy consumed worldwide for electricity generation (Figure 43).

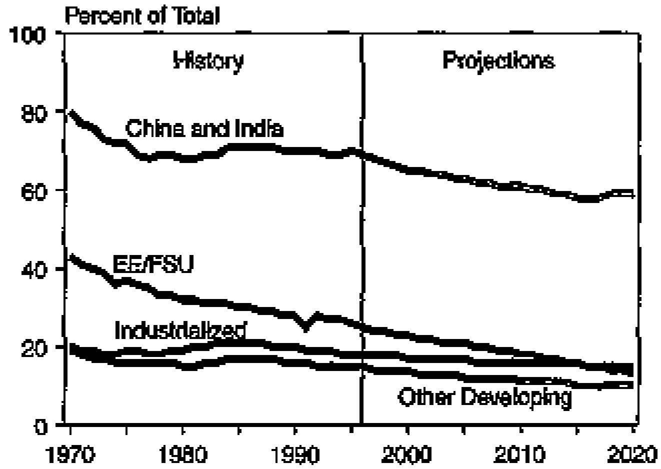
Figure 43. Coal Share of World Energy Consumption by Sector, 1996 and 2020



Sources: **1996:** Energy Information Administration (EIA), Office of Energy Markets and End Use, *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

In the *International Energy Outlook 1999* (*IEO99*) forecast, coal's share of total energy consumption falls only slightly, from 25 percent in 1996 to 23 percent in 2020. Its historical share is nearly maintained, because large increases in energy use are projected for the developing countries of Asia, where coal continues to dominate many national fuel markets. Together, two of the key countries in the region, China and India (Figure 44), are projected to account for 33 percent of the world's total increase in energy consumption over the forecast period and 90 percent of the world's total increase in coal use (on a Btu basis).

Figure 44. Coal Share of Regional Energy Consumption, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

With the exception of China, coal for electricity generation will account for virtually all the projected growth in coal consumption worldwide. In the non-electricity sectors, other energy sources—primarily, natural gas and electricity—are expected to gain market share. In China, however, coal continues to be the primary fuel in a rapidly growing industrial sector, in view of the nation's abundant coal reserves and limited access to alternative sources of energy. Consumption of coking coal is projected to decline slightly in most regions of the world as a result of technological advances in steelmaking, increasing output from electric arc furnaces, and continuing substitution of other materials for steel in end-use applications.

Because the Kyoto Protocol is not currently a legally binding agreement, the *IEO99* projections do not reflect the commitments made by the signatory countries to reduce or moderate their emissions of greenhouse gases. If their commitments do become legally binding, however, it is likely that the coal outlook for the industrialized countries will differ substantially from the *IEO99* projections (see box below). In *IEO99*, coal consumption in the industrialized countries is projected to increase by 12 percent over the forecast period, rising from 35.8 quadrillion Btu in 1996 to 40.0 quadrillion Btu in 2020.

The recent Asian financial crisis has a direct impact on the *IEO99* projections. The crisis has led to a substantial devaluation of currencies in many of the countries of developing Asia, as well as in the industrialized countries that depend on export markets in the region. As a result, many projects to build coal-fired power plants in Asia have been delayed or canceled, and patterns of international coal trade have changed significantly.

Highlights of the *IEO99* projections for coal are as follows:

- World coal consumption is projected to increase by 2.4 billion tons, from 5.2 billion tons in 1996 to 7.6 billion tons in 2020 (Figure 45).[6] World coal consumption in 2020 could be as high as 9.2 billion tons or as

Impacts of the Kyoto Protocol on the U.S. and Japanese Energy Markets

In a study completed in October 1998, the Energy Information Administration (EIA) projected that for the United States to meet its Kyoto emissions target, annual U.S. coal consumption would need to be reduced by as little as 20 percent or by as much as 80 percent (on a tonnage basis) by 2010, relative to a reference case forecast without the Kyoto carbon emissions constraints [1, Table B16]. In the study's reference case, U.S. coal consumption was projected to rise from 896 million short tons in 1996 to 1,181 million short tons in 2010.

The largest reduction in coal consumption was projected in a case that assumed the United States would be required to reduce its carbon emissions to 7 percent below the 1990 level through fuel switching, increased penetration of energy-efficient technologies, and reductions in overall energy use. Other cases modeled in the study assumed that the United States would meet its Kyoto emissions target through a combination of actions such as fuel switching, emissions trading, joint implementation, reforestation, and reductions in emissions of other greenhouse gases.

As a result of higher projected delivered energy prices in the carbon reduction cases for the EIA's 1998 study, both the overall intensity of energy (units of energy consumed per dollar of gross domestic product) and the levels of economic activity were lower, leading to reductions in total energy consumption. Consumption levels for both coal and petroleum products were lower in the carbon reduction cases than in the reference case, whereas projected consumption levels for natural gas, renewable energy, and nuclear power were higher.

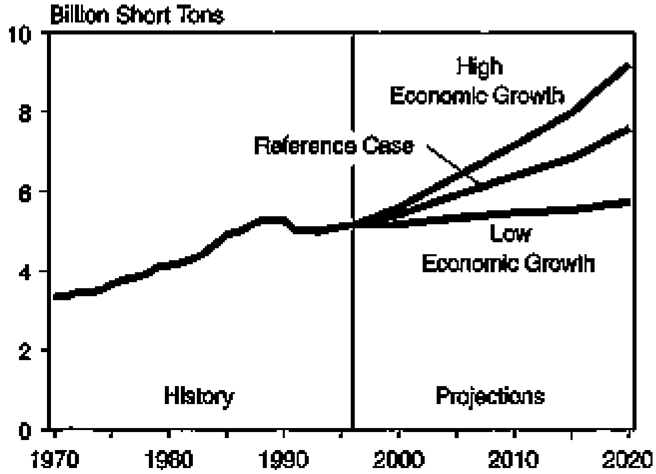
However severe the case, coal was the major "swing fuel" for making adjustments relative to Kyoto targets. In the least severe case completed for the EIA study, U.S. carbon emissions from the combustion of fossil fuels were permitted to be 24 percent above the 1990 level in 2010—still a reduction from the study's reference case, in which U.S. carbon emissions in 2010 were projected to be 33 percent higher than in 1990.

In mid-1998, the Advisory Committee for Energy—an advisory body to Japan's Ministry of International Trade and Industry (MITI)—released a forecast showing how Japan could meet its Kyoto emissions target [2]. Their study concluded that coal consumption in Japan would need to be 14 percent lower (on a tonnage basis) in 2010 than in a business-as-usual case. Interestingly, their Kyoto scenario indicated that only the supply of renewable energy would be higher. The committee projected that the supply of petroleum products, natural gas, liquefied petroleum gas (LPG), and coal would all be lower in 2010 than in their business-as-usual case, with nuclear and hydropower remaining the same.

Much of the projected reduction in carbon emissions in the Japanese study was based on assumed increases in energy efficiency and shifts away from energy-intensive activities. A Kyoto study completed by the WEFA Energy Group in 1998 projected that Japan's steam coal consumption would have to be 28 percent lower (on a Btu basis) in 2010 than it would be in a reference case forecast with no restraints on carbon emissions if Japan's commitments under the Kyoto Protocol were to be met [3].

[6] Throughout this chapter, tons refers to short tons (2,000 pounds).

Figure 45. World Coal Consumption in Three Cases, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

low as 5.7 billion tons, based on alternative assumptions about economic growth rates.[7]

- Coal use in developing Asia alone is projected to increase by 2.4 billion tons. China and India, taken together, are projected to account for 33 percent of the total increase in energy consumption worldwide between 1996 and 2020 and 90 percent of the world's total projected increase in coal use, on a Btu basis.

- China is projected to add more than 220 gigawatts of new coal-fired generating capacity by 2020 and India approximately 60 gigawatts.

- Coal's share of the world's total primary energy consumption is expected to decline from 25 percent in 1996 to 23 percent in 2020. The coal share of energy consumed worldwide for electricity generation also declines, from 38 percent in 1996 to 34 percent in 2020.

- World coal trade is projected to increase from 530 million tons in 1997 to 659 million tons in 2020, accounting for approximately 9 to 10 percent of total world coal consumption over the period. Steam coal (including coal for pulverized coal injection at blast furnaces) accounts for most of the projected increase in world coal trade.

Environmental Issues

In future years, coal will face tough challenges, particularly in the environmental area. Increased concern about the harmful environmental impacts associated with coal use has taken a toll on coal demand throughout industrialized areas. Coal combustion produces several air pollutants that adversely affect ground-level air quality.

One of the most significant pollutants from coal is sulfur dioxide, which has been linked to acid rain. Many of the industrialized countries have implemented policies or regulations to limit sulfur dioxide emissions. Such policies typically require electricity producers to switch to lower sulfur fuels or invest in technologies (primarily flue gas desulfurization (FGD) equipment) that reduce the amounts of sulfur dioxide emitted. China, the world's largest emitter of sulfur dioxide, has been successful in reducing ambient sulfur dioxide levels in major urban areas in recent years but has been unable to restrain the growth of sulfur emissions overall (see box on page 60).

A recent study completed by the International Energy Agency reported that most of the coal-fired capacity in Southeast Asian countries is not fitted with FGD equipment, primarily because of cost but also because most plants in the region currently use low-sulfur coal [4]. The study concludes that public concern over pollution in Southeast Asia is likely to increase as living standards rise, but at present the emphasis is on increasing electricity generation to satisfy demand and ensure economic growth.

In late 1998, approximately 5,000 villagers in southern Thailand staged a protest against plans for three new coal-fired power plants in the region [5]. Although the plants are being designed to burn imported low-sulfur coal, residents living nearby were under the impression that locally produced, high-sulfur lignite was to be used. Many people living in close proximity to the Mae Moe lignite-fired plant in northern Thailand have suffered serious respiratory problems attributed to high levels of sulfur dioxide emissions.

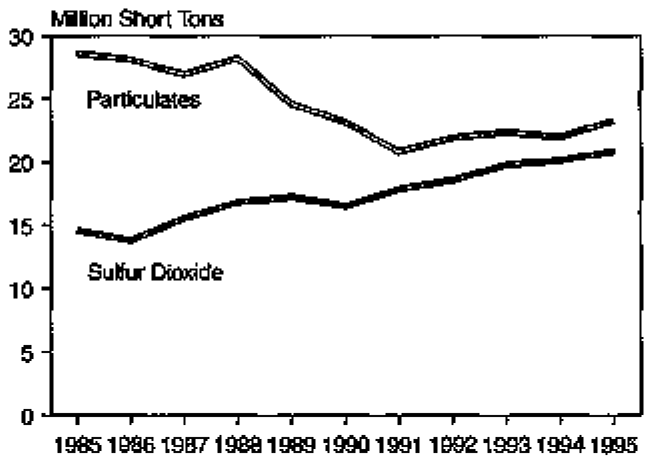
In addition to sulfur dioxide, increased restrictions on emissions of nitrogen oxides, particulates, and carbon dioxide are likely, especially in the industrialized countries. Although the potential magnitudes and costs of additional environmental restrictions for coal are uncertain, it seems likely that costs for coal-fired generation will increase. The costs of natural-gas-fired generation

[7] In the *IEO99* reference case, world gross domestic product (GDP) is projected to increase at a rate of 2.9 percent per year between 1996 and 2020. In the low and high economic growth cases, world economic growth rates are assumed to be 1.3 percent lower and 1.2 percent higher, respectively, than in the reference case. By region, the dispersion in economic growth rates across the cases is less symmetrical than for the world as a whole, resulting in slightly asymmetrical variations in the projections of world coal consumption. In the low and high economic growth cases, the expected economic growth rates for China are 3.0 percent lower and 1.5 percent higher, respectively, than in the reference case.

China: Emissions of Sulfur Dioxide and Particulates

Sulfur dioxide (SO_2) and particulates are considered by many environmental experts in China to be the ambient air pollutants of gravest concern. In 1995, SO_2 emissions in China were estimated at 20.8 million tons, and particulate emissions totaled 23.3 million tons (see figure). By comparison, SO_2 emissions in the United States were estimated at 18.6 million tons in 1995[a] and particulate emissions totaled 3.3 million tons [6]. Coal is estimated to be the source of approximately 90 percent of China's SO_2 emissions and 70 percent of its particulate emissions [7].

Emissions of Sulfur Dioxide and Particulates in China, 1985-1995



Source: National Environmental Protection Agency (NEPA), Peoples Republic of China, *China Environmental Yearbook* (various issues).

Although China's SO_2 emissions are similar to those in the United States, the direct use of coal in China in the industrial and residential sectors within or in close proximity to urban areas has created serious health problems in its major cities. As recently as 1996, five cities in China (Beijing, Shenyang, Xi'an, Shanghai, and Guangzhou) were ranked among the world's ten worst for air pollution [8, p. VIII-3].

Mortality data for China indicate that 17 percent of the deaths in China's urban areas are due to acute and chronic respiratory illnesses [8, p. VIII-3]. This is substantially higher than the 7-percent share estimated for urban areas in the United States. According to a World Bank study completed in 1997, an estimated 178,000 people in China's major cities suffer early deaths each year because of ambient pollution levels in excess of China's standards [9, p. 19].

In China, SO_2 emissions originate from a wide range of industrial sources, including power plants, which account for approximately one-third of China's total sulfur emissions, and the production of chemicals, building materials, and metals, which, taken together, account for an additional 20 percent of total sulfur emissions [8, p. VIII-2].[b] The consumption of coal for residential heating and cooking also accounts for about 20 percent of total SO_2 emissions. The widespread dispersion of point sources in China makes it more complicated than in other countries to reduce emissions through stack emission controls. In most countries, a relatively small number of centralized power plants account for the majority of total SO_2 emissions. At present, very little of China's manufacturing or generating plants are fitted with FGD equipment.

Particulate emissions originate primarily from the same sources that emit sulfur dioxide. The key industrial source of particulates is the building materials sector, accounting for almost 25 percent of total emissions, followed by power plants (approximately 20 percent) and ferrous metals (approximately 8 percent) [8, p. VIII-3]. The nonindustrial sectors, primarily residential, account for more than 25 percent of China's total emissions of particulates.

To date most efforts at reducing emissions in China have focused on the control of particulates, primarily those associated with such noncombustion processes as grinding, crushing, and sorting. Between 1986 and 1995, the average concentration of particulates in China's top ten populous cities declined from 636 micrograms per cubic meter ($\mu g/m^3$) to 300 $\mu g/m^3$ (see figure). During the same period, the share of total particulate emissions originating from noncombustion sources fell from 50 percent to 30 percent [8, Table VIII-2].

Improvements in ambient SO_2 levels have been relatively steady but less impressive than those for particulates. Between 1986 and 1995, the average annual SO_2 concentration for the ten most populous cities in China declined from 149 $\mu g/m^3$ to 91 $\mu g/m^3$. The most recent levels, however, continue to exceed the 50 $\mu g/m^3$ guideline for sulfur dioxide set forth by the World Health Organization.

The Chinese government recognizes the need to reduce pollution further, particularly in urban areas.

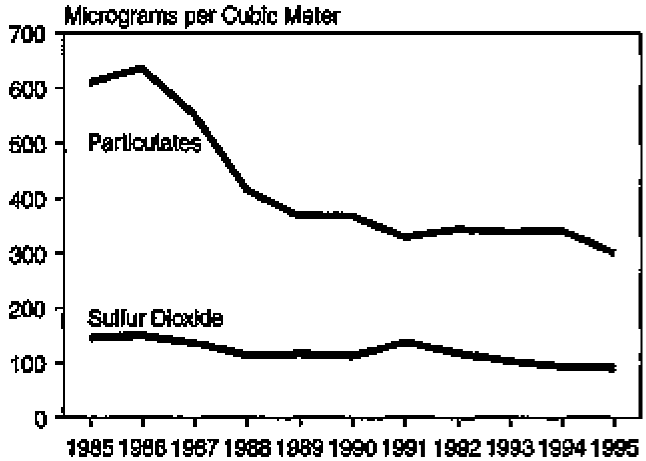
(continued on page 61)

[a]According to the U.S. Environmental Protection Agency, 87 percent of U.S. sulfur dioxide emissions in 1995 resulted from the combustion of energy fuels in the electricity generation, industrial, commercial, and residential sectors. The remaining portion originated from industrial processes (9 percent) and the use of fuels for transportation (4 percent).

[b]Based on data collected for 1993.

China: Emissions of Sulfur Dioxide and Particulates (Continued)

Ambient Air Quality for China's Ten Most Populous Cities, 1985-1995



Notes: City sizes based on population statistics for 1994. Average pollution levels calculated as the sum of annual averages reported for individual cities, divided by the number of cities.

Source: National Environmental Protection Agency (NEPA), Peoples Republic of China, *China Environmental Yearbook* (various issues).

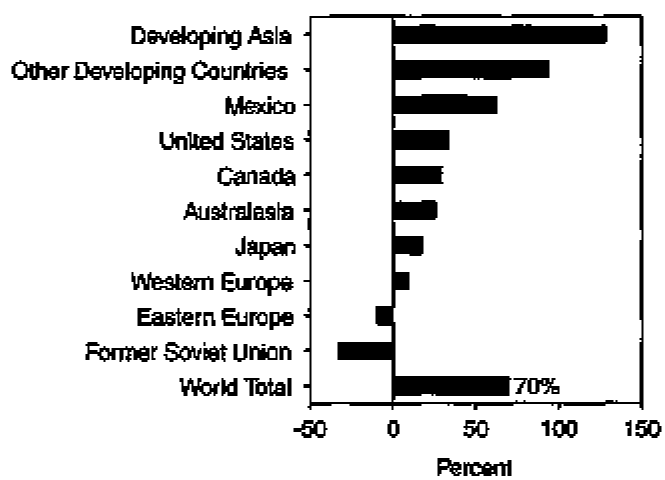
Many new laws and regulations to protect the environment have been promulgated in recent years, and various programs to control pollution, such as emission fees and pollution trading schemes, have been tested. A recently enacted program to reduce pollution levels in Beijing requires that all boilers using high-sulfur coal switch to a cleaner fuel such as natural gas or low-sulfur coal, and that building sites be walled off to contain fugitive dust from construction activities [10]. Additional means for reducing air pollution, both ongoing and under consideration, include: (1) encouraging investments in coal preparation facilities (noncombustible materials in coal contribute to increased emissions of particulates); (2) encouraging retrofits of electrostatic precipitators at existing coal-fired power plants; (3) encouraging industrial facilities to locate away from urban areas; (4) implementing additional government policies to encourage investments in less energy-intensive industries; and (5) encouraging households to switch from the use of raw coal for heating and cooking to cleaner burning fuels such as natural gas or coal briquettes [8, p. VIII-3; 9, pp. 50-51].

are not likely to be affected as much. For nuclear and hydropower, which compete with coal for baseload power generation, the future is unclear. Proposals have been put forth in several of the developed countries to phase out nuclear capacity in full or in large measure. In other countries, it has become difficult to site new capacity because of unfavorable public reaction. The siting of new large hydroelectric dams is also becoming more difficult because of increased environmental scrutiny. In addition, suitable sites for new large hydropower projects are limited.

By far the most significant emerging issue for coal is the potential for a binding international agreement to reduce emissions of carbon dioxide and other greenhouse gases. On a Btu basis, the combustion of coal produces more carbon dioxide than that of natural gas or of most petroleum products [11, Table B1]. Carbon dioxide emissions per unit of energy obtained from coal are nearly 80 percent higher than from natural gas and approximately 20 percent higher than from residual fuel oil—the petroleum product most widely used for electricity generation. In the *IEO99* forecast, carbon emissions are projected to rise between 1990 and 2010 in many countries, including increases of 33 percent for the United States, 17 percent for Japan, and 9 percent for Western Europe (Figure 46). On the other hand, carbon emissions for the former Soviet Union are projected to be 33 percent lower in 2010, and emissions in Eastern Europe are projected to be 10 percent lower. Ratification of the Kyoto Protocol could have a substantial adverse impact on coal, particularly in the United States, which relies heavily on coal to meet its energy needs and faces relatively severe cutbacks in carbon emissions from those currently projected for 2010 (Figures 46 and 47).

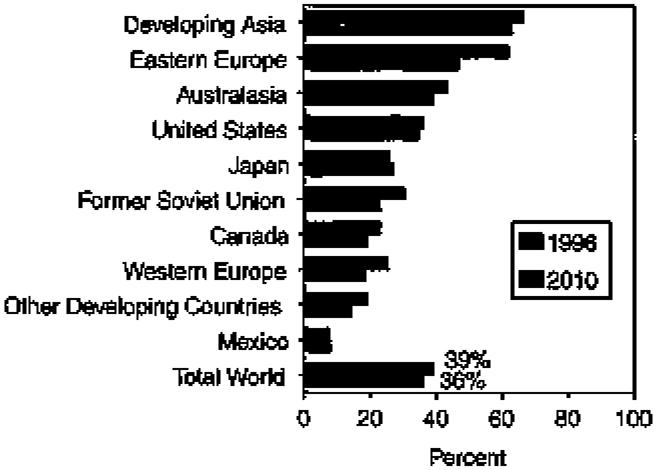
In the *IEO99* forecast, coal continues to be the second largest source of carbon emissions, accounting for

Figure 46. Projected Cumulative Growth in World Carbon Emissions by Region, 1990-2010



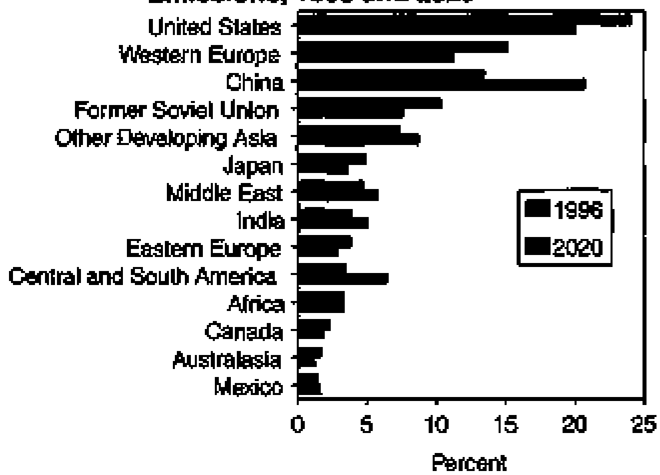
Source: Energy Information Administration, World Energy Projection System (1999).

Figure 47. Coal Share of Total Carbon Emissions by Region, 1996 and 2010



Sources: **1996:** Energy Information Administration (EIA), Office of Energy Markets and End Use, *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **2010:** EIA, World Energy Projection System (1999).

Figure 48. Regional Shares of World Carbon Emissions, 1996 and 2020



Sources: **1996:** Energy Information Administration (EIA), Office of Energy Markets and End Use, *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **2020:** EIA, World Energy Projection System (1999).

36 percent of the world total in 2020. Oil, at 39 percent in 2020, remains the largest source of carbon emissions, and natural gas accounts for almost all the remaining portion. By country, the world's dominant coal consumers—the United States and China—were also the top two contributors to world carbon emissions in 1996, at 24 percent and 13 percent of the world total, respectively (Figure 48). By 2020, however, the U.S. share of world carbon emissions is projected to decline to 20 percent, while China's share increases to 21 percent. The substantial increase in carbon emissions in China over the period is attributable to expectations of strong economic growth and the country's continuing reliance on coal as its primary source of energy.

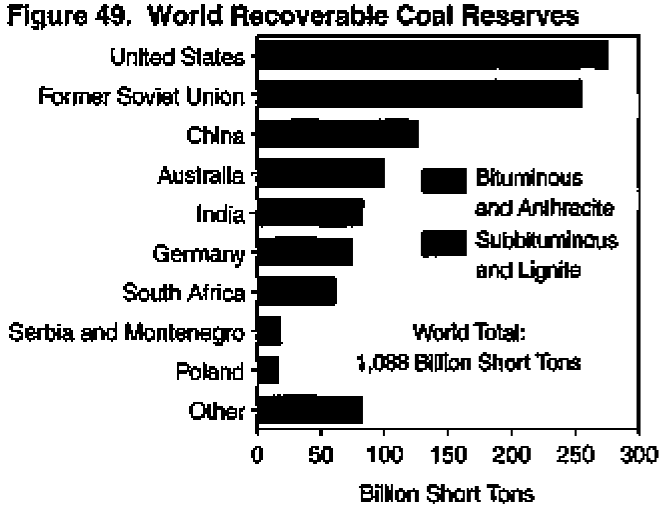
Reserves

Total recoverable reserves of coal around the world are estimated at 1,088 billion tons—enough to last another 210 years at current production levels (Figure 49).[8] Although coal deposits are widely distributed, 60 percent of the world's recoverable reserves are located in three regions: the United States (25 percent); FSU (23 percent); and China (12 percent). Another four countries—Australia, India, Germany, and South Africa—account for an additional 29 percent. In 1996, these seven regions accounted for 81 percent of total world coal production [12, Table 2.5].

Quality and geological characteristics of coal deposits are other important parameters for coal reserves. Coal is a much more heterogeneous source of energy than is oil or natural gas, and its quality varies significantly from one region to the next and even within an individual coal seam. For example, Australia, the United States, and Canada are endowed with substantial reserves of premium coals that can be used to manufacture coke. Together, these three countries supplied 85 percent of the coking coal traded worldwide in 1997 (see Table 15, below).

At the other end of the spectrum are reserves of low-Btu lignite or "brown coal." Coal of this type is not traded to any significant extent in world markets, because of its relatively low heat content (which raises transportation costs on a Btu basis) and other problems related to

Figure 49. World Recoverable Coal Reserves



Note: Data represent recoverable coal reserves as of January 1, 1997.

Source: Energy Information Administration (EIA), Office of Energy Markets and End Use, *International Energy Annual 1997*, DOE/EIA-0219(97) (Washington, DC, March 1999), Table 8.2.

[8]Recoverable reserves are those quantities of coal which geological and engineering information indicates with reasonable certainty can be extracted in the future under existing economic and operating conditions.

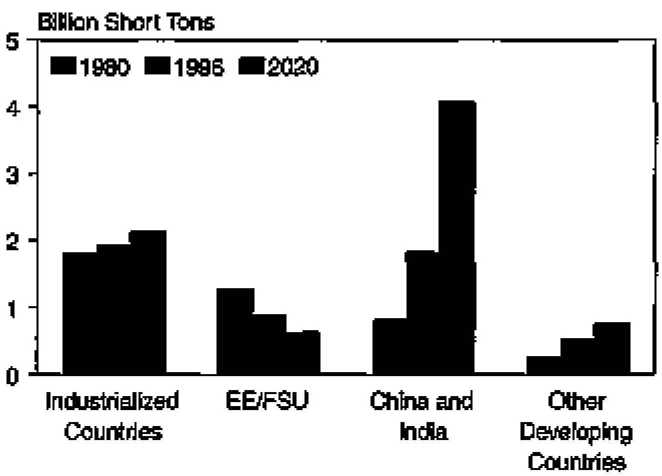
transport and storage. In 1996, lignite accounted for 19 percent of total world coal production (on a tonnage basis) [12, Tables 2.5 and 5.4]. The top three producers were Germany (206 million tons), Russia (106 million tons), and the United States (88 million tons). As a group, these countries accounted for 41 percent of the world's total lignite production in 1996. On a Btu basis, lignite deposits show considerable variation. Estimates by the International Energy Agency for coal produced in 1996 show that the average heat content of lignite from major producers in countries of the Organization for Economic Cooperation and Development (OECD) varied from a low of 4.3 million Btu per ton in Greece to a high of 12.3 million Btu per ton in Canada [13, pp. II.19-II.22].

Regional Consumption

Asia

The large increases in coal consumption projected for China and India are based on an outlook for strong economic growth (6.5 percent per year in China and 5.1 percent per year in India) and the expectation that much of the increased demand for energy will be met by coal, particularly in the industrial and electricity sectors (Figure 50). The *IEO99* forecast assumes no significant changes in environmental policies in the two countries. It also assumes that necessary investments in the countries' mines, transportation, industrial facilities, and power plants will be made.

Figure 50. World Coal Consumption by Region, 1980, 1996, and 2020



Sources: **1980 and 1996:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **2020:** EIA, World Energy Projection System (1999).

Coal remains the primary source of energy in China's industrial sector, primarily because China has limited reserves of oil and natural gas. In the non-electricity sectors, most of the increase in oil use comes from rising demand for energy for transportation. Growth in the consumption of natural gas comes primarily from increased use for space heating in the residential and commercial sectors. A substantial portion of the increase in China's demand for both natural gas and oil is projected to be satisfied by imports.

In the electricity sector in China, coal use is projected to grow by 4.0 percent a year, from 8.9 quadrillion Btu in 1996 to 22.9 quadrillion Btu in 2020. In comparison, coal consumption by electricity generators in the United States is projected to rise by 1.1 percent annually, from 18.0 quadrillion Btu in 1996 to 23.5 quadrillion Btu in 2020. One of the key implications of the substantial rise in electricity coal demand in China is that large financial investments in new coal-fired power plants and in the associated transmission and distribution systems will be needed. The projected growth in coal demand implies that China will need approximately 375 gigawatts of coal-fired capacity in 2020.[9] In 1996, China had approximately 154 gigawatts of fossil-fuel-fired (coal, oil, and gas) generating capacity [12, Table 6.4].

In China, 62 percent of the total increase in coal demand is projected to occur in the non-electricity sectors, for steam and direct heat for industrial applications (primarily in the chemical, cement, and pulp and paper industries) and for the manufacture of coal coke for input to the steelmaking process. Strong growth in steel demand is expected in China as infrastructure and capital equipment markets expand.

In India, projected growth in coal demand occurs primarily in the electricity sector. Between 1996 and 2020, coal use for electricity generation in India is projected to rise by 3.0 percent per year, from 4.4 quadrillion Btu in 1996 to 8.9 quadrillion Btu in 2020. This growth implies that India will need approximately 130 gigawatts of coal-fired capacity in 2020.[10] In 1996, India's total fossil-fuel-fired generating capacity amounted to 70 gigawatts [12, Table 6.4].

In the remaining areas of developing Asia, a substantial rise in coal consumption is expected over the forecast period, based on projected strong growth in coal-fired electricity generation in South Korea, Taiwan, and the member countries of the Association of Southeast Asian Nations (primarily Indonesia, Malaysia, the Philippines, Thailand, and Vietnam). In the electricity sector, coal use in the other developing countries of Asia (including

[9]Based on a 10-percent improvement in the average heat rate (or conversion efficiency) and a rise in the average capacity factor from approximately 55 percent in 1996 to 65 percent by 2020.

[10]Based on a 10-percent improvement in the average heat rate (or conversion efficiency) and a rise in the average capacity factor from approximately 50 percent in 1996 to 60 percent by 2020.

South Korea) is projected to rise by 3.7 percent per year, from 2.4 quadrillion Btu in 1996 to 5.7 quadrillion Btu in 2020.

With the exception of South Korea, electric utilities in the countries of developing Asia are expected to add little in the way of new coal-fired generating capacity over the forecast period [14]. Rather, most of the new coal-fired plants are to be built by independent power producers (IPPs). While much of the planned new IPP capacity was seen as a relatively sure bet a couple of years ago, the recent financial crisis has caused delays and cancellations of many of the projects planned or under construction [15].

The primary problems affecting IPP projects in the region relate to the sharp devaluation of currencies and the current economic crisis, which has caused a slowdown in the growth of both economic output and energy demand. Currency devaluations in the region have proved to be problematic for IPP projects primarily because of pressure being placed on them to accept lower prices for their electricity than were originally agreed to in their long-term contracts with electricity distributors (typically national utilities) [16, 17, 18, 19]. Because most of the costs of IPP projects in the region are based in U.S. dollars, the acceptance of lower prices by project owners would mean lower or negative returns on project investments. On the other hand, the electricity distributors are not in a position to raise rates to end-use consumers of electricity, because national governments in the region typically have control over end-use prices and are unwilling to grant requests for increases, given the current economic crisis. Reduced expectations for future growth in electricity demand also mean that less new generating capacity will be needed than previously expected, delaying or eliminating the need for some of the planned IPP projects.

The profitability of the power plants owned and operated by state-owned utilities in the region also has been adversely affected, because capital, operating, and maintenance costs incurred by the utilities have generally risen by substantial amounts since the onset of the regional economic crisis. Three main factors contribute to the cost increases: (1) payments for imported fuels usually are denominated in U.S. dollars and, thus, have increased with recent devaluations in Asian currencies; (2) equipment, much of which is imported, is denominated in U.S. dollars; and (3) interest payments have increased because of a recent downgrading of bonds issued by utilities in the region.

In Japan, coal consumption is projected to increase at a much slower pace than in the other countries of Asia. In the electricity sector, coal use is projected to rise at a rate of only 1.1 percent per year, from 1.4 quadrillion Btu in 1996 to 1.8 quadrillion Btu in 2020. The projected increase implies that Japan will need to build less than 10 gigawatts of new coal-fired generating capacity between 1996 and 2020. This is substantially different from the most recent outlook provided by Japan's Ministry of International Trade and Industry, which projects the need for 24 gigawatts of new coal-fired capacity between 1997 and 2008 [20]. The *IEO99* projections show slightly slower growth in Japan's overall electricity demand and stronger growth in natural-gas-fired electricity generation.

Western Europe

In Western Europe, environmental concerns play an important role in the competition among coal, natural gas, and nuclear power. Recently, other fuels—particularly natural gas—have been gaining an increasing economic advantage over coal. Coal consumption in Western Europe has declined by 35 percent over the past 7 years, falling from 927 million tons in 1989 to 600 million tons in 1996. The decline was slightly smaller on a Btu basis, at 28 percent, reflecting the fact that much of the decline was accounted for by reduced consumption of low-Btu lignite in Germany. The decline in coal consumption is expected to continue over the forecast period, but at a slower rate.

Between 1989 and 1996, German lignite production declined by 247 million tons [12, Table 5.4]. The sharp decline in German lignite production followed the conversion from lignite-based town gas[11] to natural gas in the eastern states of Germany after reunification in 1990, as well as substitution of natural gas and other fuels for lignite in home heating [13, p. II.201; 21]. A second factor was the collapse of industrial output in the eastern states. Reduced economic activity in eastern Germany contributed to an 8.5-percent decline in total energy consumption in Germany between 1988 and 1994. In the *IEO99* forecast, further declines in lignite production in Germany are projected to be small in view of the competitiveness of German lignite with other imported fuels and planned investments to refurbish or replace existing lignite-fired plants using best available combustion and pollution control technologies. A new 900-megawatt lignite plant to be built in the Rheinland area of Germany is expected to be the most up-to-date lignite-based power station in the world when it is completed in 2002, boasting a 43-percent conversion efficiency [13, p. I.189].

The recent trend in the consumption of hard coal in Western Europe is closely correlated with the trend in

[11] "Town gas" (or "coal gas"), a substitute for natural gas, is produced synthetically by the chemical reduction of coal at a coal gasification facility.

the production of hard coal.[12] Following the closure of the last remaining coal mines in Belgium in 1992 and Portugal in 1994, only four member States of the European Union—the United Kingdom, Germany, Spain, and France—continue to produce hard coal [22]. Since 1989, all four of these countries have seen their output of hard coal decline. In Germany, Spain, and France, recent agreements between the governments, mining companies, and labor unions on future coal production subsidies indicate that further declines in output are forthcoming. In the United Kingdom, production subsidies have been phased out, forcing coal producers into direct competition with North Sea gas and international coal.

In the United Kingdom, hard coal production declined from 111 million tons in 1989 to 56 million tons in 1996 [12, Tables 5.2 and 5.3]. Most of the decline resulted from privatization in the electricity sector, which led to a rapid increase in gas-fired generation at the expense of coal [13, Table 3.3; 23, Table 3.3]. Substantial improvements have been made in the country's mining operations in recent years, with average labor productivity rising from less than 1,000 tons per miner-year in 1989 to 2,600 tons per miner-year in 1996 [13, Table 6.5a].

Despite productivity improvements and domestic production costs that are approaching parity with imported coal, British coal producers continue to face an uncertain future [24, p. 33]. Many coal contracts between producers and utilities negotiated before the privatization of the coal industry in 1994 expired at the end of March 1998 [22, p. 21; 24]. In late 1997, initial negotiations on the renewal of the contracts indicated a strong preference among British utilities to switch from coal to natural gas. The potential negative impacts on the British coal industry and mining jobs prompted the issuance of a temporary moratorium on the construction of new gas-fired generating plants by the British government [25, 26]. In addition, Britain's energy minister requested an analysis of the nation's power industry to evaluate how the issues of fuel diversity and security of supply should be considered in the approval process for new power projects. In 1996, electricity producers in the United Kingdom consumed 60 million tons of coal, representing 77 percent of the country's total coal consumption [27].

The study—the Energy Review White Paper—was completed by the United Kingdom's Department of Trade and Industry in October 1998 [24]. The report considered issues related not only to the diversity and security of energy supply but also to the design, operation, and structure of the electricity market. One of the key findings of the review was compelling evidence that distortions in the country's wholesale electricity market (the electricity pool) are encouraging the displacement of generation from existing plants with generation from new gas-fired plants. The distortions were attributed to several factors, including the following: (1) the bidding process for the wholesale market allows small generators (e.g., new gas-fired plants) to bid a low price for their generation, thus assuring that their plants will be fully dispatched while receiving the price submitted by the highest bidder (typically large generators with coal-fired capacity) for each time period during the day; and (2) inadequate competition, particularly in the coal-fired generation sector, has led to prices in the wholesale market that are higher than necessary. In response to the study's findings, the British government has initiated a program of reforms in the electricity market intended to create a more competitive environment—one in which existing coal-fired capacity will be able to compete more effectively with generation from new gas-fired plants.

Coal subsidies continue to support high-cost production of hard coal in Germany, Spain,[13] and France. For 1996, the European Commission authorized coal industry subsidies of $6,947 million in Germany, $1,116 million in Spain, and $863 million in France [22, pp. 34-36].[14] In each country, the average subsidy per ton of coal produced exceeds the average value of imported coal (Table 14), and all three are currently taking steps to reduce subsidy payments, acknowledging that some losses in coal production are inevitable.

Germany's hard coal production, which is highly subsidized, declined from 88 million tons in 1989 to 58 million tons in 1996 [12, Tables 5.2 and 5.3]. In March 1997, the federal government, the mining industry, and the unions reached an agreement on the future structure of subsidies to the German hard coal industry. Subsidies to the industry are to be reduced from DM10.5 billion in 1996 to DM5.5 billion by 2005, resulting in an estimated decline in production to 33 million tons [13, pp. I.193-I.194]. The agreement calls for the closure of 8 to 9 of Germany's 19 hard coal mines, resulting in an estimated decline in employment from 55,000 miners in 1996 to about 36,000 in 2005. In the *IEO99* reference case, increased imports of coal are expected to compensate for a portion of the expected decline in output from indigenous mines.

In Spain, hard coal production declined from 29 million tons in 1989 to 20 million tons in 1996 [12, Tables 5.2 and 5.3]. In 1997, an agreement reached between the

[12]Internationally, the term "hard coal" is used to describe anthracite and bituminous coal. In data published by the International Energy Agency, coal of subbituminous rank is classified as hard coal for some countries and as brown coal (with lignite) for others. In data series published by the Energy Information Administration, subbituminous coal production is included in the bituminous category.

[13]In Spain, subsidies support the production of both hard coal and subbituminous coal.

[14]In local currencies, coal subsidies in 1996 were DM10.5 billion in Germany, Pta141.4 billion in Spain, and FF4.4 billion in France.

Table 14. Western European Coal Industry Subsidies, Production, and Import Prices, 1996

Country	Coal Industry Subsidies (Million 1996 Dollars)	Hard Coal Production (Million Tons)	Average Subsidy per Ton of Coal Produced (1996 Dollars)	Average Price per Ton of Coal Imported (1996 Dollars)
Germany	6,947	57.9	$120	$43
Spain	1,116	22.5	$50	$43
France	863	8.0	$108	$48

Sources: **Coal Production Subsidies:** Directorate-General XVII—Energy, European Commission, *The Market for Solid Fuels in the Community and the Outlook for 1997*, web site www.europa.eu.int (Brussels, Belgium, June 6, 1997); and U.S. Federal Reserve Bank, "Foreign Exchange Rates (Annual)," web site www.bogfrb.fed.us (January 4, 1999). **Production:** Energy Information Administration, *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1997). **Average Price of Coal Imports:** International Energy Agency, *Coal Information 1997* (Paris, France, September 1998).

government, labor unions, and the electricity sector allows subsidized coal production to continue in Spain through 2005, with output set to decline gradually to 15 million tons per year [13, pp. I.195-I.196]. In the electricity sector, the share of domestic coal that must be used in power generation will be reduced from the current level of about 40 percent to 15 percent. Spain's coal mine labor force will be reduced from 24,000 in 1996 to approximately 18,000 by 2005 through retirement and voluntary separations.

In France, production of hard coal declined from 14 million tons in 1989 to 8 million tons in 1996 [12, Tables 5.2 and 5.3]. A modernization, rationalization, and restructuring plan submitted by the French government to the European Commission at the end of 1994 foresees the closure of all coal mines in France by 2005 [22, p. 36]. The coal industry restructuring plan was based on a "Coal Agreement" reached between France's state-run coal company, Charbonnages de France, and the coal trade unions. Over the forecast period, consumption of hard coal in Spain and France is expected to decline roughly in accordance with the reductions in indigenous coal production, as other fuels—primarily natural gas, nuclear, and renewable energy—are expected to compensate for most of the reduction in domestic coal supply.

Coal use in other major coal-consuming countries in Western Europe is projected either to decline or to remain close to current levels. In the Scandinavian countries (Denmark, Finland, Norway, and Sweden), environmental concerns and competition from natural gas are expected to reduce coal use there over the forecast period. The government of Denmark has stated that its goal is to reduce the amount of coal use in the country's energy mix to 2 percent by 2030 [28]. In 1996, coal accounted for 39 percent of the country's total primary energy supply [13, p. II.172].

Italy's coal consumption is projected to remain relatively constant in the *IEO99* forecast. Factors in favor of increased coal use in Italy include: (1) a National Energy Plan which states that coal is underutilized in the country's energy mix; and (2) recent capital investments (environmental and coal-handling equipment) at two of the country's multifuel-fired generating plants so as to better accommodate the use of coal [13, p. III.125; 27, sec. 11.8]. On the other hand, Italy has a strong environmental lobby and a strong oil and gas lobby, and current and planned investments in gas pipeline infrastructure promise to increase the supply of natural gas to Italy substantially over the forecast period [27, sec. 11.8; 29].

Partly offsetting the declines in coal consumption elsewhere in Europe is a projected increase in consumption of indigenous lignite for electricity generation in Greece. Under an agreement reached by the countries of the European Union in June 1998, Greece committed to capping its emissions of greenhouse gases by 2010 at 25 percent above their 1990 level [30]—much less severe than the emissions target for the European Union as a whole, which must reduce its emissions to 8 percent below those in 1990 by 2010 [31].

Eastern Europe and the Former Soviet Union

In the EE/FSU countries, the process of economic reform continues as the transition to a market-oriented economy replaces centrally planned economic systems. The dislocations associated with institutional changes in the region have contributed substantially to declines in both coal production and consumption. Coal consumption in the EE/FSU region has fallen by 562 million tons since 1988, reaching 885 million tons in 1996 [12, Table 1.4]. In the future, total energy consumption in the EE/FSU is expected to rise, primarily as the result of increasing production and consumption of natural gas. In the forecast, coal's share of total EE/FSU energy consumption declines from 25 percent in 1996 to 13 percent in 2020, and the natural gas share increases from 41 percent in 1996 to 55 percent in 2020.

The three main coal-producing countries of the FSU—Russia, the Ukraine, and Kazakhstan—are facing similar problems. All three countries have developed national programs for restructuring and privatizing their coal industries, but they have been struggling with related technical and social problems. Of the three, Kazakhstan has shown the most rapid progress, as many of the country's mines have been purchased and are now operated by international energy companies [32].

In Russia and the Ukraine, efforts have been aimed primarily at shutting down inefficient mines and transferring associated support activities—such as housing, kindergartens, and health and recreation facilities—to local municipalities. The closure of inefficient mines in both countries has been slow, however, leading to delays in the scheduled disbursement of money, via loans, from the World Bank. In both countries, coal-mining regions continue to wield considerable political clout, putting pressure on the leadership via strikes and their ability to influence election results [33, 34]. In late 1998, Prime Minister Yevgeniy Primakov announced that privatization procedures in Russia's coal industry should be suspended [35]. He indicated that "public stability [in the country] depends on the situation in the coal industry," and that privatization efforts have not led to the expected improvements in productivity. To date, the World Bank has provided $900 million in loan assistance to the Russian coal industry and $150 million to the Ukraine [34, 36, 37, 38]. The Bank plans to disburse an additional $400 million and $150 million to the Russian and Ukrainian coal industries, respectively, when specific conditions of progress are met.

The transfer of support activities from mining associations to local municipalities has also been problematic. Most of the planned transfers in Russia and the Ukraine have already occurred, but the municipalities do not have sufficient funding [39]. Thus, the quality of health care and other services in mining communities has deteriorated considerably. Even efficient mines in Russia and the Ukraine are not without problems. Payment arrears of large customers have been making it nearly impossible for mines to pay workers and purchase needed mining supplies and equipment [40].

Poland is the key coal producer and consumer in Eastern Europe. In 1996, coal consumption in Poland totaled 179 million tons, 43 percent of Eastern Europe's total coal consumption for the year [12, Table 1.4]. Poland's hard coal industry produced 150 million tons in 1996, and lignite producers contributed an additional 69 million tons [12, Tables 5.2, 5.3, and 5.4]. In other Eastern European countries, coal consumption is dominated by the use of low-Btu subbituminous coal and lignite produced from local reserves. In 1996, the region's other important coal-consuming countries were the Czech Republic (17 percent of the region's total coal use), Romania (12 percent), Serbia (10 percent), Bulgaria (8 percent), and Hungary (5 percent). Eastern Europe relies heavily on local production, with seaborne imports of coal to the region totaling only 6 million tons in 1997 [41].

At present, Poland's hard coal industry is operating at a loss [42]. Over the past several years, a number of coal industry restructuring plans have been put forth for the purpose of transforming Poland's hard coal industry to a position of positive earnings, eliminating the need for government subsidies. The most recent plan was announced by Poland's Ministry of the Economy in April 1998. It calls for the closure of 24 of the country's 50 unprofitable mines over the next 4 years, reducing the total number of mines in Poland from 65 in 1998 to 41 by 2002. In addition, the restructuring plan aims to reduce the number of miners by nearly one-half, from 245,000 in 1998 to 138,000 by 2002 [43]. The government hopes to achieve most of the planned reduction in force through normal retirements and voluntary separations. All miners leaving the industry before retirement age (either voluntarily or involuntarily) under the restructuring program will receive financial compensation packages and assistance in either moving to a new job or establishing a business.

The Polish government projects that sales of hard coal from domestic mines will decline from 100 million tons in 1998 to 88 million tons by 2010 and to 77 million tons by 2020. The World Bank has indicated its willingness to loan the Polish government up to $1 billion over a 3-year period to help cover the costs of the restructuring program, including economic assistance for miners leaving the industry [44]. The program assumes full liberalization of coal pricing and complete liberalization of trade in coal by the year 2000.

North America

In North America, coal consumption is concentrated in the United States, which, at 983 million tons, accounted for 93 percent of the regional total in 1996. By 2020, U.S. coal consumption is projected to rise to 1,275 million tons. With its substantial supplies of coal reserves, the United States has come to rely heavily on coal for electricity generation and continues to do so over the forecast. Coal provided 52 percent of total U.S. electricity generation in 1996 and is projected to provide 49 percent in 2020 [45]. To a large extent, EIA's projections of declines in both minemouth coal prices and coal transportation rates are the basis for the expectation that coal will continue to compete as a fuel for U.S. power generation. In Canada and Mexico (the other countries of North America), coal consumption is projected to rise from 74 million tons in 1996 to 92 million tons in 2020.

Canada's increased use of coal in the *IEO99* forecast results primarily from the expected retirement of some of the country's older nuclear units after 2010, and the subsequent need to replace that generation [46].

Between 2010 and 2020, Canada's nuclear generation is projected to decline by 22 percent. In addition, a temporary decrease in Canada's nuclear generation results in some increase in coal consumption early in the forecast. During the summer of 1997, Ontario Hydro shut down 7 of its 19 nuclear reactors for major overhauls after the discovery of widespread safety and performance problems [47]. Of the 7 units shut down, 4 are located at the utility's Pickering station and 3 at its Bruce station [48, pp. 3-4]. Their combined capacity is 3.6 gigawatts.

As in other parts of the world, natural gas is expected to be the fuel of choice for most new generating capacity in Mexico. In 1996, Mexico consumed 14 million tons of coal. Two coal-fired generating plants, operated by the state-owned utility Comision Federal de Electricidad (CFE), consume approximately 10 million tons of coal annually [49], most of which originates from domestic mines.

Currently, CFE has plans to switch its dual-fired Petacalco plant, located on Mexico's Pacific coast, from oil to coal [50]. The plant has burned fuel oil since its startup in 1995, but CFE wants to switch most, if not all, of the plant's six generating units to coal by sometime in 1999. The utility estimates that the 2.1-gigawatt plant will require more than 5 million tons of imported coal annually. A coal import facility adjacent to the plant, with an annual throughput capacity of more than 9 million tons, will serve both the power plant and a nearby integrated steel mill [51].

Africa

In Africa, coal production and consumption are concentrated almost entirely in South Africa. In 1996, South Africa produced 227 million tons of coal, 71 percent of which was routed to domestic markets and the remainder to exports [12, Table 2.5]. South Africa ranks third in the world in coal exports, behind Australia and the United States, and is projected to maintain that position over the forecast. South Africa holds the distinction of being the world's largest producer of coal-based synthetic liquid fuels. In 1996, almost one-fifth of the coal consumed in South Africa (on a Btu basis) was used to produce coal-based synthetic oil, which in turn accounted for more than one-fourth of all liquid fuels consumed in South Africa during the year [13, 52].

For Africa as a whole, coal consumption is projected to increase by 48 million tons between 1996 and 2020, primarily to meet increased demand for electricity. Contributing to the increase in electricity demand is South Africa's commitment to an aggressive electrification program, which aims to increase the percentage of households connected to the electricity grid from 44 percent at the end of 1995 to 75 percent by 2000 [52, 53].

There are also substantial opportunities for trade in electricity and natural gas between South Africa and neighboring countries. New power transmission lines have been completed or are planned to facilitate flows of electricity between South Africa, Mozambique, Zimbabwe, Swaziland, and Namibia [52]. Such international connections could open new markets for underutilized or idle coal-fired power plants in South Africa.

Elsewhere in Africa, the completion of four additional coal-fired units at Morocco's Jorf Lasfar plant near Casablanca should increase coal consumption there from about 2 million tons in 1996 to more than 5 million tons [54, 55]. When all units are completed, the plant is expected to account for approximately one-third of Morocco's total power generation.

Central and South America

Coal has not been an important source of energy in Central and South America, accounting for less than 6 percent of the region's total energy consumption since 1970. In the electricity sector, hydroelectric power currently meets much of the region's electricity demand. Over the forecast period, both hydropower and natural gas are projected to fuel much of the projected increase in electricity generation.

In 1996, Brazil accounted for 67 percent of South America's total coal demand (on a Btu basis), with Colombia, Chile, and Argentina accounting for much of the remaining portion. In Brazil, the steel industry accounts for almost two-thirds of the country's total coal consumption, relying on imports of coking coal to produce coke for use in its blast furnaces [13, p. III.13]. In the forecast, increased use of coal for steelmaking (both coking coal and coal for pulverized coal injection) accounts for much of the projected increase in Brazil's coal consumption [56]. New power projects in Colombia and Brazil account for most of the remaining growth in coal consumption projected for South America [57].

In Central America, petroleum products and hydropower are the key sources of primary energy consumption (accounting for 70 and 24 percent of the total, respectively, in 1996) [58]. The only coal consumption in the region is a small quantity used in Panama for industrial purposes [56, p. 65]. Coal use in the region is set to increase somewhat, however, with the completion of a 120-megawatt coal-fired generating plant in Guatemala in 1999 [59, 60]. The plant, being built by a consortium of U.S. and Guatemalan companies, will be the first coal-fired power plant in Central America.

Middle East

Turkey accounts for most of the coal consumed in the Middle East. In 1996, a total of 72 million tons of coal was consumed in Turkey, most of it low-Btu, locally produced lignite (approximately 7.3 million Btu per ton) [12, Tables 2.5 and 5.4; 13, p. II.21]. Over the forecast period, Turkey's coal consumption (both lignite and hard coal) increases by 22 million tons, primarily to fuel additional coal-fired generating capacity.

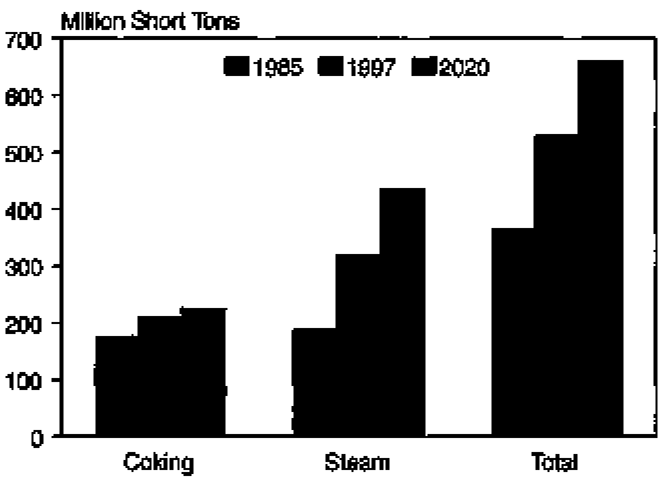
Israel and Iran accounted for most of the remaining 8 million tons of coal consumed in the Middle East in 1996 [12, Table 1.4]. Over the forecast, Israel's coal consumption is projected to rise by approximately 5 million tons with the completion of two new coal-fired generating plants between 1999 and 2005 [13, pp. III.125 and III.133; 61]. Israel's state-owned utility, Israel Electric Corporation, estimates that coal-fired plants will meet approximately 60 percent of the country's electricity needs in the post-2000 period [62]. In Iran, approximately 1 million tons of coal consumption has been met historically by indigenous suppliers [12, Table 2.5]. In addition, Iran's National Steel Corporation imports approximately 0.5 million tons of coking coal annually [63, 64].

Trade

Overview

The amount of coal traded in international markets is small in comparison with total world consumption. In 1997, world imports of coal amounted to 530 million tons (Table 15 and Figure 51), representing 10 percent of total consumption. By 2020, coal imports are projected to rise to 659 million tons, accounting for a 9-percent share

Figure 51. World Coal Trade, 1985, 1997, and 2020

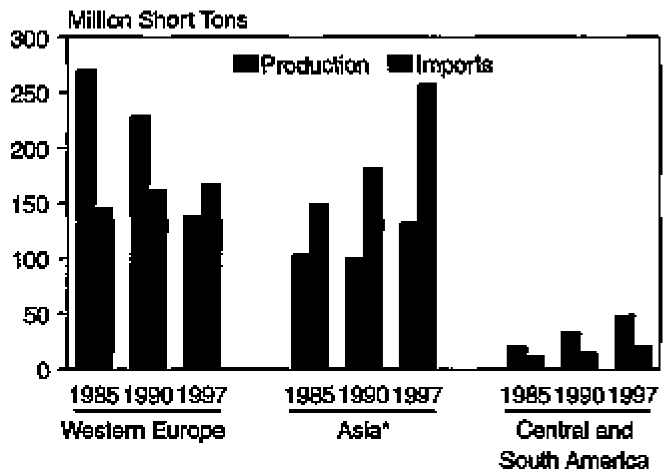


Sources: **1985:** Energy Information Administration (EIA), *Annual Prospects for World Coal Trade 1987*, DOE/EIA-0363(87) (Washington, DC, May 1987). **1997:** International Energy Agency, *Coal Information 1997* (Paris, France, September 1998); Financial Times Energy Press, *International Coal Report, Coal Year 1998* (London, UK, May 1998); and EIA, *Quarterly Coal Report, October-December 1997*, DOE/EIA-0121(97/4Q) (Washington, DC, May 1998). **2020:** EIA, National Energy Modeling System, run IEO99.D012099B.

of world coal consumption. Although coal trade has made up a relatively constant share of world coal consumption over time and should continue to do so in future years, the geographical composition of trade is shifting.

In recent years, international coal trade has been characterized by relatively stable demand for coal imports in Western Europe and expanding demand in Asia (Figure 52). Rising production costs in the indigenous coal industries in Western Europe, combined with continuing pressure to reduce industry subsidies, have led to substantial declines in production there, creating the potential for significant increases in coal imports; however, slow economic growth in recent years and increased electricity generation from natural gas, nuclear, and hydropower have curtailed the growth in coal imports. Conversely, growth in coal demand in Japan, South Korea, and Taiwan in recent years has contributed to a substantial rise in Asian coal imports.

Figure 52. Production and Imports of Hard Coal by Region, 1985, 1990, and 1997



*Data for Asia exclude China, India, and Australasia.

Note: Production and imports include data for anthracite, bituminous, and subbituminous coal.

Sources: Energy Information Administration, Office of Energy Markets and End Use, International Statistics Database.

The recent worldwide financial crisis has introduced some changes and uncertainties in international coal markets, affecting trade patterns and prices from late 1997 to the present. In international markets, coal prices are negotiated in U.S. dollars. Thus, as a result of recent currency devaluations against the dollar, coal producers in countries such as Australia and South Africa have been able to lower their export prices substantially while continuing to receive the same or higher prices in local currencies [19, 48, 65].[15] Their coal sales have consequently increased, primarily at the expense of other

[15]Between May 1996 and August 1998, the Australian dollar lost 26 percent of its value compared with the U.S. dollar. Similarly, between January 1996 and August 1998, the South African rand lost 42 percent of its value [66].

Table 15. World Coal Flows by Importing and Exporting Regions, Reference Case, 1997, 2010, and 2020
(Million Short Tons)

Exporters	Importers											
	Steam[a]				Coking[b]				Total			
	Europe[c]	Asia	America	Total[d]	Europe[c]	Asia	America	Total[d]	Europe[c]	Asia	America	Total[d]
						1997						
Australia	8.6	71.2	1.2	81.1	15.8	67.4	4.6	92.3	24.4	138.6	5.8	173.4
United States	13.2	6.1	12.2	31.4	31.3	7.8	13.0	52.2	44.5	13.9	25.2	83.5
South Africa	38.3	17.6	1.3	63.3	0.3	3.0	2.2	6.3	38.6	20.6	3.5	69.6
Former Soviet Union	5.4	2.4	0.0	11.5	4.0	3.2	0.0	6.3	9.4	5.6	0.0	17.8
Poland	17.2	0.0	0.0	17.9	3.4	0.0	0.4	5.2	20.6	0.0	0.4	23.1
Canada	1.4	4.4	0.8	5.5	6.2	23.4	3.2	34.7	7.6	27.8	4.0	40.2
China	1.4	26.5	0.0	28.9	0.1	6.8	1.0	4.8	1.5	33.2	1.0	33.7
South America	27.0	0.0	7.8	30.8	0.8	0.2	0.1	2.2	27.8	0.2	7.9	33.0
Indonesia[e]	6.5	29.5	2.0	48.8	2.1	4.2	0.2	6.6	8.6	33.7	2.2	55.3
Total	119.0	157.7	25.3	319.1	63.9	115.9	24.8	210.4	182.9	273.7	50.1	529.6
						2010						
Australia	8.0	117.4	1.1	16.4	26.2	75.8	8.3	110.3	34.2	193.1	9.4	236.7
United States	13.5	9.3	6.3	29.1	29.1	2.5	16.9	48.6	42.7	11.8	23.3	77.7
South Africa	48.8	24.9	2.2	76.0	0.0	5.1	0.0	5.1	48.8	30.0	2.2	81.0
Former Soviet Union	7.7	2.8	0.0	10.5	3.3	2.2	0.0	5.5	11.0	5.0	0.0	16.0
Poland	8.0	0.0	0.0	8.0	3.6	0.0	0.0	3.6	11.7	0.0	0.0	11.7
Canada	2.9	4.8	0.1	7.8	0.9	30.0	4.7	35.6	3.8	34.8	4.8	43.4
China	0.0	37.0	0.0	37.0	0.0	6.1	0.0	6.1	0.0	43.1	0.0	43.1
South America	33.9	0.0	16.1	50.0	0.0	0.0	0.0	0.0	33.9	0.0	16.1	50.0
Indonesia[e]	7.3	52.0	0.0	59.3	0.0	0.0	0.0	0.0	7.3	52.0	0.0	59.3
Total	130.2	248.2	25.6	404.2	63.2	121.7	29.9	214.8	193.3	369.9	55.7	618.9
						2020						
Australia	6.4	130.5	0.3	137.2	25.6	79.1	10.3	115.0	32.0	209.7	10.5	252.2
United States	8.9	9.7	7.4	25.9	28.8	3.2	19.5	51.5	37.6	12.9	26.9	77.5
South Africa	36.2	37.3	2.5	76.0	0.0	4.6	0.0	4.6	36.2	41.9	2.5	80.6
Former Soviet Union	7.7	3.9	0.0	11.6	3.3	2.2	0.0	5.5	11.0	6.1	0.0	17.1
Poland	5.5	0.0	0.0	5.5	3.4	0.0	0.0	3.4	8.9	0.0	0.0	8.9
Canada	1.8	7.0	0.1	8.9	1.3	31.5	5.0	37.8	3.1	38.5	5.1	46.7
China	0.0	42.6	0.0	42.6	0.0	6.6	0.0	6.6	0.0	49.2	0.0	49.2
South America	39.5	0.0	18.1	57.5	0.0	0.0	0.0	0.0	39.5	0.0	18.1	57.5
Indonesia[e]	4.2	65.2	0.0	69.4	0.0	0.0	0.0	0.0	4.2	65.2	0.0	69.4
Total	110.2	296.1	28.3	434.6	62.4	127.3	34.8	224.5	172.6	423.4	63.1	659.1

[a]Reported data are consistent with data published by the International Energy Agency (IEA). The standard IEA definition for "steam coal" includes coal used for pulverized coal injection (PCI) at steel mills; however, some PCI coal is reported by the IEA as "coking coal."

[b]Includes primarily coal consumed to produce coal coke. According to the IEA, a minor exception for 1997 trade data is the classification of 9.6 million tons of coal imported to Japan for PCI at blast furnaces as coking coal. Similarly, the IEA reports that some exports of coal from Australia, South Africa, Indonesia, and Colombia to be used for PCI at steel mills is classified as coking coal, consistent with data reported by importing countries and industry terminology and practice.

[c]Coal flows to Europe include shipments to the Middle East and Africa.

[d]For 1997, total world coal flows include a balancing item used by the International Energy Agency to reconcile discrepancies between reported exports and imports. The 1997 balancing items by coal type were 17.1 million tons (steam coal), 5.8 million tons (coking coal), and 22.9 million tons (total).

[e]For 1997, coal exports from Indonesia include shipments from other countries not modeled for the forecast period. The 1997 non-Indonesian exports by coal type were 6.8 million tons (steam coal), 3.6 million tons (coking coal), and 10.4 million tons (total).

Notes: Data exclude non-seaborne shipments of coal to Europe and Asia. Totals may not equal sum of components due to independent rounding. The sum of the columns may not equal the total, because the total includes a balancing item between importers' and exporters' data.

Sources: 1997: International Energy Agency, Coal Information 1997 (Paris, France, September 1998); Energy Information Administration, Quarterly Coal Report, October-December 1997, DOE/EIA-0121(97/4Q) (Washington, DC, May 1998); and International Coal Report, Coal Year 1998 (London, United Kingdom: Financial Times Energy Press, May 1998). Projections: Energy Information Administration, National Energy Modeling System, run IEO99.D012099B.

exporting countries, and lower prices have been paid by coal importers. At present, it is not clear how long the current problems in financial markets will persist. Clearly, a reversal in the Australian and South African currencies from the current downward trend would lead to an increase in coal export prices.

Asia

Despite recent setbacks, Asia's demand for imported coal remains poised for additional increases over the forecast period, based on strong growth in electricity demand in the region and the need for additional coal-fired generating capacity. Continuing the recent historical trend, Japan, South Korea, and Taiwan are projected to account for much of the regional growth in coal imports over the forecast period.

Japan continues to be the world's leading importer of coal and is projected to account for 27 percent of total world imports in 2020 [67], the same share as in 1997 [13, Table 4.2]. In 1997, Japan produced 5 million tons of coal for domestic consumption and imported 143 million tons. The closure of Japan's Miike mine in March 1997 leaves the country with only about 3.5 million tons of production capacity at two remaining coal mines [68]. Production at those mines is expected to end when the government eliminates industry subsidies in 2001, leaving all of Japan's coal requirements to be met by imports [13, p. I.180; 69].

As the leading importer of coal, Japan has been influential in the international coal market. Historically, contract negotiations between Japan's steel mills and coking coal suppliers in Australia and Canada established a benchmark price for coal that was used later in the year as the basis for setting contract prices for steam coal used at Japanese utilities [70]. Other Asian markets also tended to follow the Japanese price in settling contracts.

Japan's influence, however, has declined somewhat over the past several years, and the benchmark pricing system that was so influential in setting contract prices was abandoned by Japan's steel mills in 1996. What seems to be occurring in the Asian coal markets is a shift away from contract purchases to the spot market. Liberalization of the Japanese electricity market is placing increased cost-cutting pressure on utilities, making them less inclined to accept some benchmark price negotiated by any of the other individual utilities. The shift to more competitive coal markets in Asia implies that coal producers in Australia and other exporting countries will be under increased pressure to reduce mining costs in order to maintain current rates of return. It also means that less competitive suppliers, such as the United States, will find it difficult to increase or maintain coal export sales to the region.

China and India, which import relatively small quantities of coal at present, are expected to account for much of the remaining increase in Asian imports. Imports by China and India have the potential to be even higher than the projected amount, but it is assumed in the forecast that domestic coal will be given first priority in meeting the large projected increase (2.3 billion tons) in coal demand.

During the 1980s, Australia became the leading coal exporter in the world, primarily by meeting increased demand for steam coal in Asia. Some growth in exports of coking coal also occurred, however, as countries such as Japan began using some of Australia's semi-soft or weak coking coals in their coke oven blends. As a result, imports of hard coking coals from other countries, including the United States, were displaced. Australia's share of total world coal trade, which increased from 17 percent in 1980 to 33 percent in 1997, is projected to reach 38 percent in 2020 [71]. Australia should continue as the major exporter to Asia, continuing to meet approximately one-half of the region's total coal import demand.

Europe

Coal imports to Europe are projected to decline slightly over the forecast period. Most of the decline occurs in the countries of Western Europe, where strong environmental lobbies and competition from natural gas are expected gradually to reduce the reliance on coal for electricity generation. Coking coal consumption in Western Europe is also expected to decline over the forecast period. Improvements in the steelmaking process will continue to reduce the amount of coal required for steel production, and strict environmental standards are expected to result in the closure of some of the region's older coke batteries.

With the exception of Germany, coal imports to Western Europe are not expected to increase to compensate for reductions in indigenous coal production. Rather, increased use of natural gas, renewable energy, and nuclear power (primarily in France) is expected to fill the gap in energy supply left by the continuing declines in the region's indigenous coal production. Declines in coal imports by Western European countries in the *IEO99* forecast are partially offset by small increases projected for Turkey, Romania, Morocco, Israel, and Croatia.

In 1997, the leading suppliers of imported coal to Europe were the United States (24 percent), South Africa (21 percent), and South America (15 percent). Over the forecast period, low-cost coal from South America is projected to meet an increasing share of European coal import demand, displacing some coal from such higher cost suppliers as the United States and Poland.

The Americas

Compared with European and Asian coal markets, imports of coal to North and South America are relatively small, amounting to only 50 million tons in 1997 (Table 15). Brazil imported 34 percent of the 1997 total, followed by Canada (30 percent) and the United States (15 percent) [13, p. I.128]. Almost all (91 percent) of the imports to Brazil were coking coal [13, p. III.13].

Over the forecast period, coal imports to the Americas increase by 13 million tons, with most of the additional tonnage going to Brazil and Mexico, both of which are expected to import additional amounts of coal for use at integrated steel plants [56, 72, 73]. Coal imports to the Brazilian steel industry are projected to rise substantially as the result of strong growth in domestic steel demand and a continuing switch from charcoal to coal coke. In addition to coking coal, Mexico is projected to import additional quantities of steam coal for electricity generation. Additional imports of coal to the Americas are projected to be met primarily by producers in Colombia, Venezuela, and Australia.

Coking Coal

Historically, coking coal has dominated world coal trade, but its share has steadily declined, from 55 percent in 1980 to 40 percent in 1997 [74]. In the forecast, its share of world coal trade continues to shrink, falling to 34 percent by 2020. In absolute terms, despite a projected decline in imports by the industrialized countries, total world coking coal trade is projected to show a slight increase over the forecast period as the result of increased demand for steel in the developing countries. Increased imports of coking coal are projected for South Korea, Taiwan, India, Brazil, and Mexico, where expansions in blast-furnace-based steel production are expected.

Factors that contribute to the decline in coking coal imports in the industrialized countries are continuing increases in steel production from electric arc furnaces (which do not use coal coke as an input) and technological improvements at blast furnaces, including greater use of pulverized coal injection equipment and higher average injection rates per ton of hot metal produced. One ton of pulverized coal (categorized as steam coal) used in steel production displaces approximately 1.4 tons of coking coal [75, 76]. In 1996, the direct use of pulverized coal at blast furnaces accounted for 13 percent of the coal consumed for steelmaking in Japan and the European Union [13, Tables 3.9 and 3.10; 27].

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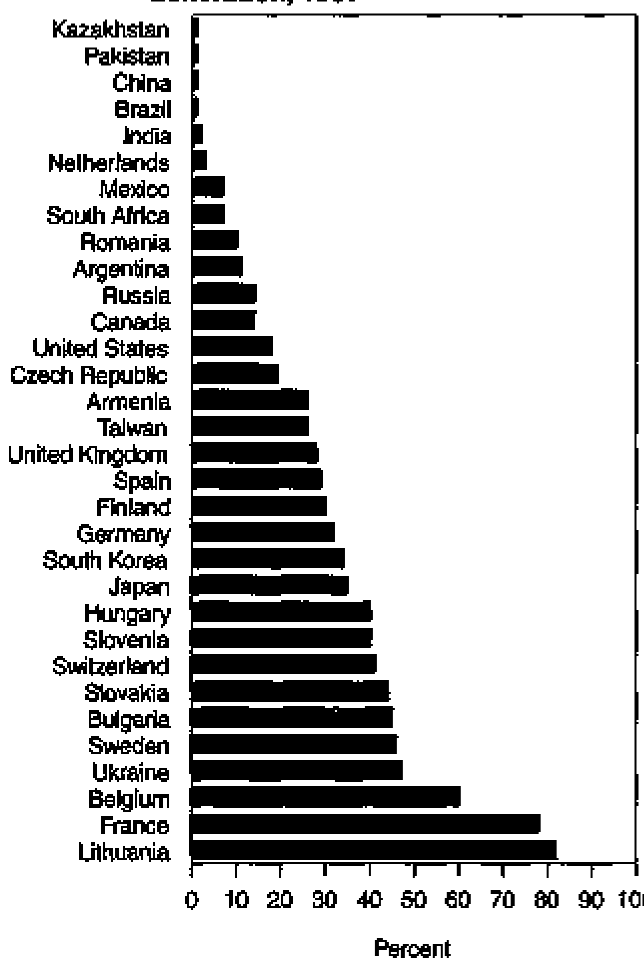
Nuclear Power

Nuclear electricity generation remains flat in the IEO99 reference case, representing a declining share of the world's total electricity consumption. Net reductions in nuclear capacity are projected for most industrialized nations.

In 1997, a total of 2,276 billion kilowatthours of electricity was generated from nuclear power worldwide, providing 17 percent of the world's electricity generation. Among the countries with operating nuclear power plants, national dependence on nuclear power for electricity varies greatly (Figure 53). Ten countries met at least 40 percent of their total electricity demand with generation from nuclear reactors.

The prospects for nuclear power to maintain a significant share of worldwide electricity generation are uncertain, despite projected growth of 2.5 percent per year in total electricity demand through 2020. Over the long term, of the regions shown in Figure 53, only the developing nations and Japan are projected to have net additions to nuclear power capacity. In other regions, countries that are operating older reactors and have other, more economical options for new generating capacity are expected to let their nuclear capacity fade as current nuclear units are retired.

Figure 53. Nuclear Shares of National Electricity Generation, 1997

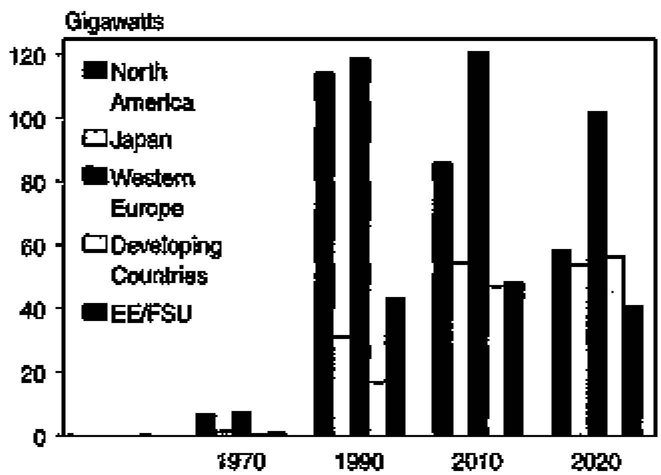


Source: International Atomic Energy Agency, *Nuclear Power Reactors in the World 1997* (Vienna, Austria, April 1998).

In the *IEO99* reference case, worldwide nuclear capacity is projected to increase from 352 gigawatts in 1997 to 356 gigawatts in 2010. After 2010 it begins to decline, reaching 311 gigawatts in 2020. Aggressive plans to expand nuclear capacity, mainly in the Far East, drive the near-term increase. Plant retirements in the United States and other countries exceed new additions, contributing to the decline later in the forecast (Figure 54). Developing Asian countries are projected to add 30.6 gigawatts by 2020, but the industrialized nations overall lose 69.9 gigawatts. Nuclear generation in the reference case remains flat over the forecast period, representing a declining share of electricity consumption.

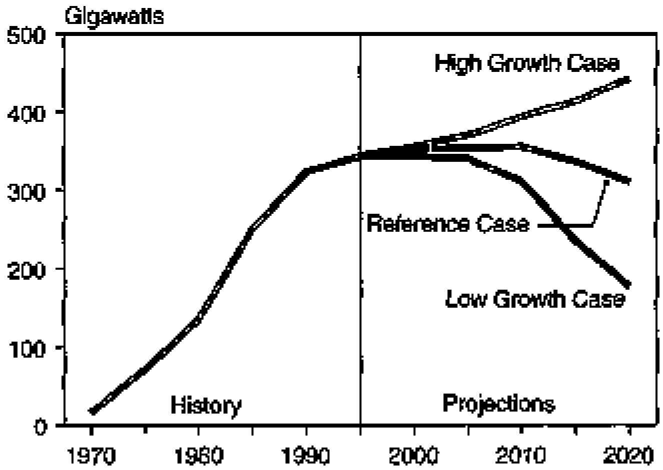
Three nuclear capacity scenarios were developed for *IEO99*, to provide a range of outcomes reflecting the uncertainty surrounding future investment in nuclear technology (Figure 55 and Table 16). The reference case reflects a continuation of present trends; the low and

Figure 54. World Nuclear Capacity by Region, 1970-2020



Sources: **History:** International Atomic Energy Agency, *Nuclear Power Reactors in the World 1997* (Vienna, Austria, April 1998). **Projections:** Based on detailed assessments of country-specific nuclear power programs.

Figure 55. World Nuclear Capacity in Three Cases, 1970-2020



Sources: **History:** International Atomic Energy Agency, *Nuclear Power Reactors in the World 1997* (Vienna, Austria, April 1998). **Projections:** Based on detailed assessments of country-specific nuclear power programs.

high cases present more pessimistic and optimistic views of the future of the nuclear power industry. For the United States, the reference case assumes that the current trend of early reactor retirements will continue if the economics do not justify continued operation, resulting in the retirement of almost one-quarter of current units before their licenses expire. Six units are projected to receive license renewals for an additional 20 years, but the remainder are assumed to retire at the end of their current licenses. For foreign nuclear projections, the reference case takes into account announced schedules for completion of units under construction and any announced retirement dates. Also considered are political environments, national energy plans, construction management experience, and financial conditions. Complete country-by-country listings of the projections for the reference, low, and high nuclear cases are provided in Appendixes A, B, and C.

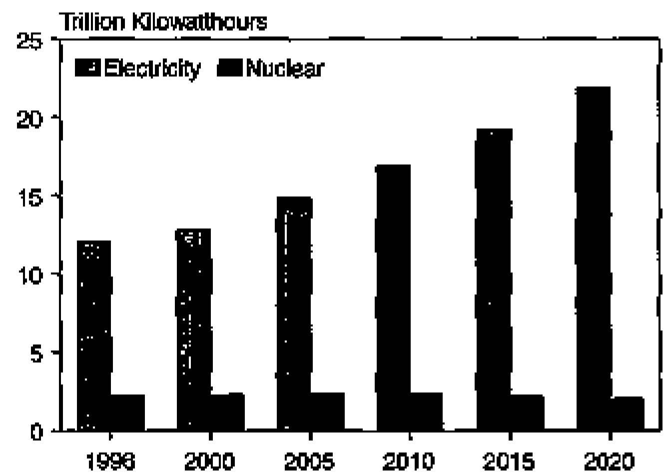
The low growth case projects a more significant decline in nuclear capacity orders, along with additional retirements of existing units. In the United States, reactors are assumed to face higher aging-related expenses, leading to more early retirements. The forecast for worldwide capacity in 2020 is 178 gigawatts, a 49-percent decline from current capacity. The high growth case reflects a slight revival for the nuclear power industry, with net capacity growth of 1 percent annually over the forecast period. In the United States, the high growth case assumes that aging effects will be limited, causing more reactors to seek license renewals. The high growth projections generally are based on assumptions that construction times for new units will be shorter, and that provisions will be made to extend the operating lives of existing units beyond current retirement dates. *IEO99* does not address the Kyoto Protocol agreement; however, if there are limits on carbon emissions in the future and, in particular, fees associated with carbon emissions, the relative economics of operating nuclear power plants could improve (see box on page 78).

Nuclear generation in the reference case remains fairly flat, with a declining share of the world's electricity consumption (Figure 56). Some key developments affecting the nuclear power industry in 1998 include:

- **Plants continue to be retired early in North America.** 1998 began with the announcement by Commonwealth Edison that the two Zion units in Illinois would be shut down permanently [4]. Later in the year, Millstone 1 was retired in Connecticut [5]. Owners cited high costs as making the units noncompetitive. Canada brought its Bruce 3 and 4 units off line, completing the shutdown of eight older units as part of a plan to focus on improving management at newer nuclear facilities.

- **Competition in the U.S. electric industry leads to sales of nuclear plants.** In the first deal of its kind, GPU Incorporated sold its Three Mile Island 1 unit to the U.S.-British joint venture AmerGen Energy Company [6]. Later in the year, Entergy Corporation outbid AmerGen to buy Boston Edison's Pilgrim nuclear station [7]. Boston Edison has been selling off all its generating units under the Massachusetts State plan to open the electricity generation market to competition. Both AmerGen and Entergy own and operate multiple nuclear stations, and they plan to use their experience to lower operating costs at the newly acquired sites. Industry experts expect this trend to continue, with owners of single-unit plants selling their plants, leading to a consolidation of the nuclear industry.

Figure 56. World Nuclear and Total Electricity Consumption, 1996-2020



Sources: **1996:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

Table 16. Historical and Projected Operable Nuclear Capacities by Region, 1996-2020
(Net Gigawatts)

Region	1996[a]	1997[b]	2000	2005	2010	2015	2020
			Reference Case				
Industrialized	283.4	283.6	278.2	269.5	260.6	233.8	213.7
United States	100.8	99.0	94.8	87.4	74.2	56.4	48.9
Other North America	16.2	13.3	12.5	11.6	11.6	11.6	9.3
Japan	42.4	43.9	43.7	44.6	54.3	53.4	53.6
France	59.9	62.9	63.1	62.9	64.3	64.3	61.5
United Kingdom	12.9	13.0	13.0	13.0	11.9	11.8	10.6
Other Western Europe	51.2	51.6	51.2	50.2	44.4	36.5	29.9
EE/FSU	46.3	46.3	48.3	49.1	48.2	49.4	40.8
Eastern Europe	9.8	9.8	10.7	12.7	11.5	10.9	10.5
Russia	19.8	19.8	22.7	21.1	21.5	21.7	19.3
Ukraine	13.8	13.8	12.1	12.1	12.1	14.0	9.5
Other FSU	2.8	2.8	2.8	3.1	3.1	2.7	1.6
Developing	21.4	22.0	25.5	36.0	47.0	54.2	56.4
China	2.2	2.2	2.2	6.7	11.5	14.7	18.6
South Korea	9.1	9.8	13.0	13.9	14.9	16.2	15.0
Other	10.1	10.1	10.3	15.3	20.5	23.3	22.7
Total World	351.1	351.9	352.0	354.6	355.8	337.4	311.0
			Low Growth Case				
Industrialized	283.4	283.6	276.4	264.3	232.1	165.1	125.0
United States	100.8	99.0	94.8	86.8	72.1	45.0	31.8
Other North America	16.2	13.3	11.6	11.6	11.6	7.6	3.3
Japan	42.4	43.9	43.7	43.8	39.6	30.2	26.1
France	59.9	62.9	62.9	62.9	62.9	55.7	51.1
United Kingdom	12.9	13.0	12.7	12.3	11.4	8.1	6.6
Other Western Europe	51.2	51.5	50.7	47.1	34.5	18.5	4.1
EE/FSU	46.3	46.3	44.6	44.9	42.8	35.7	20.8
Eastern Europe	9.8	9.8	9.8	9.9	10.6	9.1	5.8
Russia	19.8	19.8	20.8	20.1	17.4	14.1	8.4
Ukraine	13.8	13.8	11.2	12.1	13.7	11.4	6.7
Other FSU	2.8	2.8	2.8	2.7	1.2	1.2	0.0
Developing	21.4	22.0	23.4	32.1	37.6	35.5	31.9
China	2.2	2.2	2.2	6.7	8.7	8.7	8.7
South Korea	9.1	9.8	11.4	12.3	11.8	12.5	10.7
Other	10.1	10.1	9.8	13.0	17.1	14.3	12.5
Total World	351.1	351.9	344.4	341.3	312.5	236.4	177.8
			High Growth Case				
Industrialized	283.4	283.6	279.5	278.1	281.2	277.2	282.7
United States	100.8	99.0	95.5	93.2	85.5	79.4	78.2
Other North America	16.2	13.3	12.5	11.6	11.6	11.6	13.3
Japan	42.4	43.9	43.7	45.3	54.8	58.4	65.8
France	59.9	62.9	63.1	63.1	64.3	67.2	71.6
United Kingdom	12.9	13.0	13.0	13.0	12.6	12.1	11.9
Other Western Europe	51.2	51.5	51.8	51.9	52.4	48.5	42.0
EE/FSU	46.3	46.3	50.1	52.6	56.8	63.9	70.2
Eastern Europe	9.8	9.8	11.6	12.7	13.4	13.4	12.1
Russia	19.8	19.8	22.7	23.6	24.6	28.8	33.3
Ukraine	13.8	13.8	13.1	13.1	15.0	16.4	17.8
Other FSU	2.8	2.8	2.8	3.2	3.8	5.3	6.9
Developing	21.4	22.0	26.2	39.8	56.2	72.8	89.3
China	2.2	2.2	2.2	6.7	11.5	17.2	24.6
South Korea	9.1	9.8	13.0	14.9	16.8	19.6	21.9
Other	10.1	10.1	11.0	18.3	27.9	36.0	42.8
Total World	351.1	351.9	355.7	370.6	394.2	413.9	442.2

[a]Status as of December 31, 1996.
[b]Status as of December 31, 1997. Data are preliminary and may not match other EIA sources.
Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding.
Sources: **United States:** Energy Information Administration, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998). **Foreign:** Based on detailed assessments of country-specific nuclear power programs.

Nuclear Power and the Kyoto Protocol

In December 1997, parties from the 1992 Framework Convention on Climate Change, meeting in Kyoto, Japan, agreed to a new set of commitments for reducing greenhouse gas emissions. In another meeting in Buenos Aires in November 1998 a 2-year Plan of Action was adopted to establish deadlines for finalizing details of the Kyoto Protocol agreement. To become legally binding, the Protocol must be signed and ratified by at least 55 countries, including developed countries accounting for at least 55 percent of the 1990 carbon dioxide emissions from all the developed nations. If the Protocol is ratified, it will require significant shifts in energy use among the participants, because energy use is a major source of greenhouse gas emissions. Other possible options to reach the target emissions levels include emissions trading between countries (which is not yet well defined) and forestry activities that create emission absorbing sinks. It may also be possible for one country to receive credits for projects that reduce emissions in other countries. Overall, the final targets still are quite aggressive, and significant shifts in fuel usage are likely to be required in most countries.

The Protocol targets several greenhouse gases, the most important of which is carbon dioxide. The use of fossil fuels in electricity generation is a key source of carbon emissions, whereas generation from nuclear power and renewable technologies is essentially carbon-free. The use of nuclear power as a means to meet emissions goals was not specifically mentioned in the Kyoto talks; however, it could be argued that continued or increased use of nuclear technology will make it easier to meet the targets. Most renewable technologies are still relatively expensive and cannot consistently provide large amounts of energy. In contrast, nuclear technology is well developed, and many countries already have significant experience in building and operating plants. Thus, nuclear power may be a more attractive option for meeting short-term goals. Building new nuclear capacity is generally more expensive than building new coal- or gas-fired plants; but if carbon restrictions are enacted, the costs of carbon emissions from fossil-fueled generation will have to be considered, and nuclear expansion may be economically justifiable.

In the United States, nuclear power accounted for 19 percent of the Nation's total electricity production in 1996, reducing total 1996 carbon emissions by an estimated 5 to 12 percent.[a] The Energy Information Administration (EIA) report on the impacts of the Kyoto Protocol analyzed several carbon reduction cases for the United States, examining various options for meeting the emissions target [1]. Whereas in the reference case for the EIA study (no carbon restrictions) 52 percent of nuclear capacity was projected to be retired between 1996 and 2020, the carbon reduction cases projected the retirement of at most 38 percent of current U.S. nuclear capacity; and in the most restrictive case, which assumed that no international trading of permits would be allowed, only 7 percent was projected to be retired. Retirements were determined on the basis of plant economics. A penalty was applied to the cost of fossil fuels relative to their level of emissions in the carbon reduction cases, which made coal- and gas-fired generation more expensive. Under these conditions, nuclear power was more economical to operate, and life extensions were projected for more units.

In the EIA analysis of the Kyoto Protocol impacts, only life extension of existing nuclear plants was allowed (with no new nuclear capacity), except in one sensitivity case. In that case, assuming a domestic carbon emissions reduction target of 3 percent below 1990 levels, it was assumed that new nuclear capacity could be built at about 8 percent below current estimates for the first plants of a new technology. The resulting projections showed about 40 gigawatts of new nuclear capacity being built after 2015, along with a lower carbon price (by 17 percent) and lower electricity prices (by 4 percent) in 2020 than in the same case with no new nuclear capacity being built. For new nuclear capacity to be able to penetrate the market, however, investment in the first few plants would be needed, with a likelihood that not all the capital costs of the investment would be recovered.

Nuclear power currently accounts for about 17 percent of the world's electricity production and 6 percent of total energy production. One recent study has estimated that world carbon emissions would grow by 5 to 25 percent if all nuclear units were shut down and replaced with fossil-fuel generation [2]. A study by the Nuclear Energy Agency (NEA) developed three potential paths of nuclear power development over the next 50 years, analyzed the feasibility of each scenario, and then determined the impacts of the different scenarios on carbon emissions [3]. The three nuclear scenarios varied significantly, from a complete phaseout of nuclear power (virtually no worldwide generation by 2040) to steady growth in nuclear development, with the nuclear share of world electricity generation reaching 35 percent in 2050. The third scenario assumed short-term stagnation, with nuclear units being retired

(continued on page 79)

[a]This calculation assumes that the 675 billion kilowatthours of electricity generated by nuclear plants would have been replaced by some combination of conventional coal- and gas-fired technologies.

Nuclear Power and the Kyoto Protocol (Continued)

even earlier than under the phaseout scenario, followed by revival that would spark development matching that in the steady growth case by 2050. All three scenarios are possible, although the growth scenarios would present challenges to the nuclear industry related to the assumed rate of new construction.

The NEA's steady growth case resulted in a projected nuclear construction rate of 25 to 35 gigawatts per year worldwide. The revival scenario was even higher in the later years, reaching 55 to 75 gigawatts per year from 2045 to 2050. Estimates of carbon emissions reductions were calculated, assuming that a mix of fossil-fueled power plants emitting, on average, 360 grams of carbon per megawatthour of electricity generated were avoided by operating nuclear capacity. Current worldwide nuclear capacity represents avoidance of around 1.8 billion metric tons of carbon equivalent per year. The NEA steady growth scenario projected an increase, reaching annual avoided emissions of 6.3 billion metric tons by 2050. Cumulative avoided emissions through 2050 ranged from 55 billion metric tons in the phaseout scenario to 200 billion metric tons in the steady growth case.

For *IEO99*, a forecast of carbon emissions was developed for the high growth nuclear forecast, which assumed more nuclear license renewals and more construction of new nuclear plants. All other assumptions about economic growth, energy consumption, and electricity demand were unchanged from the reference case. The calculation of carbon emissions assumed that the additional consumption of nuclear energy in the high growth case would directly replace coal use in the electricity sector. In the reference case, worldwide carbon emissions from electricity generation reach 3,271 million metric tons by 2020; the high growth case would reduce emissions by 206 million metric tons (6 percent). The largest reduction in carbon emissions would be in the EE/FSU region, which also would have the largest increase in nuclear capacity in the high growth case relative to the reference case forecast.

The nuclear industry still must face the current challenges of high construction costs and public concern about safety and nuclear waste storage. In the long run, however, expansion of nuclear power could be a partial solution for some regions to meet strict carbon emission limits without cutting energy growth.

- **Nuclear utilities in the United States plan to extend plant operating lives.** Two utilities provided the U.S. Nuclear Regulatory Commission with applications for 20-year extensions of the operating lives of nuclear power plants. Baltimore Gas and Electric was the first applicant, requesting license renewal for its Calvert Cliffs plant [8]. Duke Power also submitted an application for its Oconee plant [9].

- **The nuclear waste storage issue remains unresolved in the United States.** The U.S. Department of Energy (DOE) was required to begin accepting high-level radioactive waste from utilities on February 1, 1998; however, no permanent facility is available for high-level waste storage. DOE has stated that it will not accept waste until a storage facility is completed, and most utilities filed lawsuits against DOE requesting that waste transfers begin immediately. After several legal rounds, the U.S. Circuit Court of Appeals ruled that DOE need not begin collecting waste until it opens a safe site. The court also said that operators could seek compensation for the delay. The ruling was later upheld by the U.S. Supreme Court after both sides filed appeals [10]. Yankee Atomic Electric Company, owner of three retired nuclear units, has been granted summary judgment in its cases against DOE, ruling that the only question to be decided at trial is how much to award in damages (a total of $268 million has been requested for the three units) [11].

- **India and Pakistan test nuclear weapons.** In May and June 1998, first India and then, in response, Pakistan detonated nuclear weapons. The United States automatically imposed economic sanctions against both countries, which were eased later in the year [12]. Both countries have declared moratoria on further nuclear testing and have committed to move toward adherence to the Comprehensive Test Ban Treaty by September 1999. It is uncertain whether the tests and reactions to them will affect future nuclear power investment in India and Pakistan.

- **Trade sanctions between the United States and China are lifted.** The U.S. government removed restrictions on exports of nuclear technology to China [13]. For the first time since 1989, U.S. nuclear vendors will be able to compete for the substantial business available building new nuclear reactors in China. The Chinese have already made significant progress in developing a nuclear infrastructure, which includes nuclear designs from Canada, France, and Russia.

- **New German government promises complete nuclear phaseout.** A new coalition of the Social Democratic Party and the Green Party elected in Germany included in its platform a vow to remove from service all nuclear plants, with no compensation to the operators [14]. No timetable has been suggested. Nuclear operators insist that the newer units can be run safely for 40 years, and that early shutdown would not be economically justified. It is difficult to gauge how successful the phaseout will be, given that it is driven mainly by politics rather than economics. The *IEO99* low growth case assumes a complete phaseout by 2020. The reference case assumes that some older units will be removed from service after 2000, but that newer units will be allowed to run for 35 to 40 years.

- **Swedish utility successfully fights government-imposed shutdown.** The Swedish government voted in 1980 to phase out nuclear power; however, it has not yet retired a single unit. In 1997 the government chose the Barsebaeck plant as the first to be shut down, with the first unit scheduled to close by July 1, 1998. Sydkraft fought the decision in court, which ruled that it would be unlawful to force closure until a judicial review of the government's phaseout program is conducted [15].

Regional Activity

Developing Asia

Countries in developing Asia currently operating nuclear power plants include China, South Korea, Taiwan, India, and Pakistan, and all expect some growth in the future. At the end of 1997, the five countries had 18.6 gigawatts of nuclear capacity on line. By 2020, nuclear capacity in the region is projected to be between 30.0 and 76.9 gigawatts, including at least one nuclear unit in North Korea, and—in the high growth case—new programs in Indonesia, Thailand, the Philippines, and Vietnam.

The current Asian economic crisis may cause financing concerns in the short term and, possibly, delay orders of nuclear plants. Recovery is expected for the region's national economies over the next several years, however, along with a return to baseline projections for long-term economic and energy demand growth. South Korea, currently the largest operator of nuclear power in the region, with 12 operable units totaling 9.8 gigawatts, is projected to have between 10.7 and 21.9 gigawatts on line by 2020. China's expected growth is even more striking: by 2020 China is projected to have at least 8.7 gigawatts of nuclear capacity operating, four times the current capacity; and in the high nuclear growth case, China's nuclear capacity is projected to reach 11 times its current level.

Several new units were completed in South Korea during 1997 and early 1998. Wolsong 2, a 650-megawatt pressurized heavy water reactor (PHWR), began commercial operation in July 1997, and a third unit at the site was completed a year later [16]. The fourth and final unit at the Wolsong site should be brought on line during 1999. The Wolsong units were built and designed by Atomic Energy of Canada Limited (AECL), but all remaining units under construction are of the designated Korean standardized design. The third unit at the Ulchin site, a pressurized light-water reactor (PWR) of standard design, entered service in 1998 [17].

The dramatic fall in the Asian stock market toward the end of 1997, and the resulting economic crisis in South Korea in particular, could reduce the likelihood of investment in new nuclear construction. The Korean government's Long-term Power Development Plan was delayed by 8 months as a result of the economic crisis, and forecasts of electricity demand growth were scaled back. As a result, the schedule for new power plants was pushed back to accommodate slower growth [18]. A further problem in developing new nuclear power plants in South Korea could be siting. In late 1998, the president of Korea Electric Power Corporation (Kepco) decided to reopen the site selection process—disregarding a list of potential sites prepared by his predecessor [19]. Nuclear proponents argue that this will make it more difficult to find new sites, but Kepco claims the decision was made to include the communities in the process, making it more democratic.

China also has ambitious plans to build additional nuclear power plants to meet rapid growth in electricity demand. Construction is underway for the next two units at the Qinshan site, 600-megawatt PWRs of a Chinese design. Two additional units to be constructed at the site will be 700-megawatt PHWRs supplied by AECL. Construction has also begun on two PWRs of French design at Lingao. Russia and China finally signed a contract for two 1,000-megawatt units based on a modernized Russian design [20]. The project, which has been under discussion for several years, was delayed when China changed the proposed location. The units will be built in Jiangsu Province, on China's northeastern seaboard, where there is a pressing demand for electricity.

In Taiwan, two 1,350-megawatt advanced boiling water reactors (ABWRs) are under construction at the Lungmen power station. Currently, there are no plans for any further nuclear investment in Taiwan, and there is strong opposition to nuclear power from the public. The Taiwan state utility has stated, however, that increasing nuclear energy would be the most effective method to reduce carbon dioxide emission without sacrificing economic development [21]. Government officials have said that no new nuclear plants will be built before 2020.

Other Developing Countries

Other developing countries that currently operate nuclear power plants include Argentina, Brazil, and

South Africa. Countries with the potential to have nuclear programs in place by 2020 include Cuba, Iran, Egypt, and Turkey. Argentina's two nuclear units provided 11 percent of the country's electricity in 1997. Brazil's one nuclear unit supplied just 1 percent of total electricity generation. South Africa has two nuclear units currently operable, which provided 7 percent of the country's electricity generation in 1997. No new nuclear units are planned in South Africa. Argentina has one unit under construction, and Brazil has two units in the construction pipeline. Given the uncertainties, there is a wide range of possible capacity outcomes (1.9 to 12.4 gigawatts) between now and 2020.

Most of the other developing countries do not have the capital for large nuclear programs, and it is likely that they would need financial and technical assistance before undertaking nuclear power construction. Successful completion of Cuba's Juragua station will require international assistance. Russia has agreed to complete two units for Iran, at the Bushehr site, where construction was started in the 1970s.

A Turkish utility is in the process of evaluating three bids from suppliers for Turkey's first nuclear station. Bids were received from Nuclear Power International (Siemens design), AECL, and Westinghouse. Turkey has twice previously requested bids but has yet to follow through with an order. While the new generating capacity is needed in Turkey, the political parties have not shown much support for nuclear projects [22].

Industrialized Asia

In the industrialized countries of Asia, only Japan has a well-established nuclear program, with 54 units totaling 43.8 gigawatts of operable capacity at the end of 1997. Japan's nuclear share of electricity in 1997 was 34 percent. A 1,315-megawatt boiling water reactor (BWR) was brought on line at the Kashiwazaki Kariwa site during 1997; this is the seventh and final unit planned for the site. In March 1998, Japan's first nuclear unit—Tokai 1, a 159-megawatt gas-cooled reactor—was permanently shut down [23].

Japan has ambitious plans for further nuclear expansion, mainly to help achieve energy independence; however, the uncertainties surrounding the financial market in Asia, as well as increases in public opposition to nuclear power in Japan will affect new construction decisions. In the *IEO99* reference case, Japan's nuclear capacity is projected to increase by 9.7 gigawatts between 1997 and 2020. The capacity forecasts for 2020 range from 28.1 gigawatts in the low nuclear growth case to 65.8 gigawatts in the high growth case. The current expansion plan includes 10 units assumed to be completed by 2010 in the reference case. After 2010, the reference case assumes that the current level of nuclear capacity will be maintained through 2020 either by the operation of existing units past 40 years or by replacing retired units with new nuclear capacity. The low growth case assumes that all construction plans will be deferred, and that no new construction will be completed by 2020.

Japan's nuclear power future is uncertain not only because of the economic crisis. After decades of public acceptance of nuclear power, public opinion has begun to turn, apparently as a result of a recent series of accidents and coverups. A fire and explosion at the Tokai-mura reprocessing plant, although resulting in negligible impacts on and off site, was a significant event. Power Reactor and Fuel Development Corporation (PNC) officials allegedly tried to cover up elements of the incident, leading to criminal charges and investigations, and negative publicity in Japan. Concern with PNC started after the 1995 Monju reactor sodium leak, when company officials were alleged to have altered video footage showing the damage from that event. A final event in 1998—a low-level radiation leak at PNC's Fugen Advanced Thermal Reactor, which went unreported for more than 24 hours—further eroded public confidence in the company [24]. Government plans still call for future development of nuclear power, especially as a means to cut greenhouse gas emissions, but whether the plans can be completed without strong public support remains to be seen.

Western Europe

Western Europe relies heavily on nuclear power to satisfy its electricity demand. In 1997, nuclear generation from Western European countries represented 37 percent of worldwide nuclear generation. In France and Belgium, 77 and 57 percent, respectively, of the national demand for electricity was supplied from nuclear power plants. Overall, however, the trend in Western Europe is away from nuclear power builds, and most countries in the region have frozen all nuclear construction plans. In the reference case, only France is projected to bring one new nuclear unit on line between 1997 and 2020. Eight other West European countries are projected to have net decreases in total nuclear capacity as a result of plant retirements.

In France, Chooz-B2, a 1,455-megawatt PWR of a new French design, was connected to the electricity grid in April 1997. Another unit of the same design, Civaux 1, was brought on line just before the end of 1997 [25]. After the completion of one more unit, no further units are planned for construction in France. In the Netherlands, the 55-megawatt Dodewaard plant was shut down permanently in March 1997. The small BWR had operated well for 28 years, but it could not compete economically with other generating units [26]. Finland may become the next European country to order a new nuclear unit. Two nuclear utilities in Finland have undertaken environmental impact assessments for additional nuclear units at their respective sites [27]—an essential prerequisite under Finnish law before any new development can be considered. Two units at the Loviisa site recently received approval for increases in output, as well as 10-year extensions of their operating licenses.

Both the Swedish and German governments have voted for eventual phaseout of all nuclear power capacity. The Swedish government is in the midst of trying to force the first closure at Sydkraft's Barsebaeck plant. The utility is pursuing a number of legal actions to save the reactor from forced closure; however, it is also negotiating with the government on various compensation plans in return for the shutdown of the plant.

The new German government has also called for a phased shutdown of all 19 German nuclear stations, which currently provide more than 30 percent of the country's electricity [28]. The new coalition partners, the Social Democratic Party (SPD) and the environmentalist Green Party, disagree on the progress of the phaseout, with the SPD suggesting it will occur over several decades and the Greens originally demanding that all stations be shut down within 5 years. The coalition agreement does set a deadline of 1 year to complete talks with the nuclear industry on future energy policy, after which legislation will be put in place to close plants without compensation. The German power industry has threatened to sue the government for damages if plants are shut down without their consent [29].

North America

The three nations of North America—the United States, Canada, and Mexico—all have nuclear power programs. The U.S. program is by far the largest in the region. In 1997, the nuclear share of electricity generation in the United States was 18 percent; in Canada it was 14 percent; and Mexico's two units supplied 7 percent of the country's electricity. Total nuclear capacity in the region is expected to decline over the forecast in all cases, as existing units age and are removed from service. By 2020, U.S. nuclear capacity is projected to decrease by 51 percent from the 1997 level in the reference case, due to retirements and the lack of new orders. In Canada, with no new orders projected in the reference case, capacity decreases by 4.0 gigawatts by 2020. Projected capacity in the region in 2020 ranges between 35.1 and 96.5 gigawatts under the different retirement assumptions of the low and high nuclear growth cases.

Ontario Hydro (OH), the operating utility for the majority of the nuclear units in Canada, has begun an extensive program to improve the performance of its nuclear plants. As part of the plan, OH shut down seven of the oldest units—three at the Pickering A site (where a fourth unit has been dormant since 1996) and four units at Bruce A. Five of the seven were off line by the end of 1997, and the remaining two were shut down in the spring of 1998. The units may be refurbished and brought back on line eventually. The first priority for the utility, however, is to improve performance at the units that remain operable. OH has budgeted $3.5 billion (Canadian) for fossil fuel and purchased power to make up for the planned 5-year shutdown of the older units [30].

The deregulation of the electricity industry in the United States is affecting the Nation's commercial nuclear industry in several different ways: some units have been shut down prematurely; others have been sold; and still others are expected to continue operating beyond current retirement dates. Several units were retired during 1997 and 1998. In August 1997 both the Maine Yankee and Big Rock Point reactors were shut down permanently [31, 32]. In 1998, Commonwealth Edison permanently closed its two Zion units, and the Millstone 1 unit was retired in Connecticut. The two utilities applying for license renewal are Baltimore Gas and Electric and Duke Power, for the Calvert Cliffs and Oconee plants, respectively. A decision from the Nuclear Regulatory Commission is not likely for 3 to 5 years, after an extensive review of technological and environmental issues.

Low-cost nuclear units are competitive with other technologies, and reductions in costs may be possible through improved management. In the first deal of its kind, GPU Incorporated sold its Three Mile Island 1 unit to the U.S.-British joint venture AmerGen Energy Company. AmerGen was created to buy U.S. plants that may be struggling and improve operations so that they become competitive and commercially successful in the restructured market. It is a partnership between British Energy (operators of 15 nuclear reactors in the United Kingdom's deregulated electricity market) and PECO Energy, operators of the Peach Bottom and Limerick stations in Pennsylvania.

Eastern Europe and the Former Soviet Union

There were 69 nuclear units operating in the EE/FSU region during 1997, producing 250.7 billion kilowatthours of electricity; 75 percent of the electricity from nuclear plants in the region was generated in the FSU. Reliance on nuclear power varies in this region, with Lithuania supplying 82 percent of its electricity from nuclear power, Russia 14 percent, and Kazakhstan less than 1 percent. Several countries in the region have ambitious plans for additional nuclear capacity, but there are many challenges that are likely to limit new nuclear builds. With the potential for future projects uncertain, the region's nuclear capacity is projected to decline by 5.5 gigawatts between 1997 and 2020. The low and high growth cases forecast a range of outcomes, from a loss of 25.5 gigawatts to a gain of 23.9 gigawatts in total nuclear capacity by 2020.

Romania's first full year of operation of the Cernavoda nuclear station produced 10 percent of total national electricity production in 1997, and the reactor, a Canadian-designed PHWR, achieved a capacity factor of 87 percent [33]. Construction of Mochovce 1 in Slovakia was near completion in 1998. Several teams of international experts planned to inspect the reactor before startup to review safety improvements. The project was completed by Czech and Russian engineers, with limited German and French involvement [34]. The upgraded design attempted to incorporate all essential safety modifications recommended by the International Atomic Energy Agency. Kazakhstan has completed feasibility studies for a plant in the southern part of the country and was expected to make a decision by yearend 1998 on whether to build the three-unit nuclear station [35]. The proposed plant would be designed and constructed with Russian help. Kazakhstan is considering nuclear power expansion because it has substantial uranium reserves, and the main alternative, coal, is very expensive.

Russia is in the midst of an economic crisis, causing potential investors to leave the market and delaying new nuclear construction, which is dependent on private financing. A further concern is that the utilities have been unable to pay workers for several months, driving morale down and causing threats of worker strikes. Additionally, reactor maintenance and repairs have been delayed because of a lack of funds, causing ongoing concerns over reactor safety. Safety of older reactors is also a concern in the Ukraine, where debate continues regarding when the final operating unit at the Chernobyl site will be permanently closed. An agreement was made by the Ukraine to close the station by 2000 in exchange for financing to complete two new nuclear reactors currently under construction. The financing has not come through as promised, however, and Ukraine officials have threatened to keep the Chernobyl unit running until the new reactors are completed and able to replace the power currently provided by the older unit.

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Hydroelectricity and Other Renewable Sources

Renewable energy use is projected to increase by 62 percent between 1996 and 2020. Almost half the increase is expected in the developing world, where large-scale hydroelectric projects still are being undertaken.

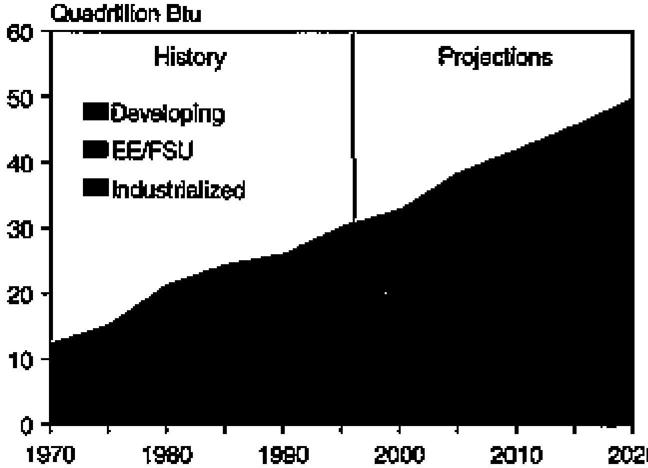
Low prices for oil and natural gas in world energy markets continued to diminish the potential for rapid development of renewable energy sources worldwide. Oil prices hit 20-year lows in 1998, in part because the Asian economic crisis resulted in lower worldwide demand. Even production cut agreements by some major oil producers, such as Saudi Arabia, Mexico, and Venezuela, failed to provide measurable price recovery during 1998.

On the positive side, the Kyoto Climate Change Protocol proposals to cut greenhouse gas emissions levels may provide an opportunity for growth in demand for renewable energy. Several European Union member countries have pledged to increase the use of renewables, and the European Union itself has pledged to increase installed wind capacity on the continent to 10 gigawatts by 2010 [1]. Overall, however, the International Energy Agency projects that some 853 gigawatts of total installed electricity generating capacity will be required by European members of the Organization of Economic Cooperation and Development by 2010 [2]. Denmark's Energy 2000 program set a goal of 1.5 gigawatts of installed wind capacity by 2005, and 1.1 gigawatts had been brought on line by the end of 1997 [3, p. 23]. Germany's Enquete Commission on "Preventative Measures to Protect the Earth's Atmosphere" identified 29 measures to help the country reduce carbon emissions by 25 to 30 percent below their 1987 level, including the promotion of wind energy and photovoltaics [4].

Further, there are signs that some large energy companies, such as Enron Corporation, Royal Dutch/Shell, and British Petroleum (BP), are expanding their interest in renewables. In 1997 Enron Corporation acquired the American wind power developer, Zond Corporation, and German wind turbine manufacturer, Tacke Windtechnik GmbH. BP announced plans to increase its solar technology sales to $1 billion within 10 years, including plans to invest $6.5 million (U.S.) in its solar photovoltaic cell production plant in Madrid, Spain, in an effort to double production of solar photovoltaic cells [5]. BP also pledged to reduce the company's greenhouse gas emissions by 10 percent relative to 1990 levels. Royal Dutch/Shell announced a similar objective to be achieved by 2002 [6].

In the *International Energy Outlook 1999* (*IEO99*), the outlook for hydroelectricity and other renewable resources remains similar to that published in *IEO98*. Worldwide, hydroelectric and other renewable energy use is projected to increase by 62 percent over the forecast period, growing from 31 quadrillion Btu in 1996 to nearly 50 quadrillion Btu in 2020. Almost half the total growth is projected for the developing world, where large-scale hydroelectric projects boost the level of renewable energy consumption (Figure 57).

Figure 57. World Consumption of Hydroelectricity and Other Renewables by Region, 1970-2020



Sources: History: Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). Projections: EIA, World Energy Projection System (1999).

In the *IEO99* reference case, projections of hydroelectricity and other renewables include only on-grid renewables. While noncommercial fuels from plant and animal sources remain an important source of energy, especially in the developing world, comprehensive data on the use of noncommercial fuels are not available and, as a result, are not included in the projections. Similarly, dispersed renewables (renewable energy consumed on the site of its production, such as solar panels used for water heating) are not included in the projections, because there are few extensive sources of international data on their use.

Major developments affecting the renewables market in 1998 include:

- China and India pledged increases in large-scale hydroelectric development in 1998. China completed its 3.3-gigawatt Ertan hydroelectric station, which began operating in August 1998. Hydroelectric projects currently under construction in China amount to some 32 gigawatts of installed generating capacity. In India, 12 large-scale projects—adding up to 3.7 gigawatts of installed hydroelectric capacity—have been given government approval. All the projects are slated for completion by 2002 [7].
- In the United States, the California Energy Commission established a financial support program for renewable energy resources, which will be funded by a small tax per kilowatthour of electricity sold to ratepayers of the State's utilities. The tax, to be levied between 1998 and 2002, should provide renewable projects with some $162 million in financial incentives.
- Wind development in Western Europe remains strong, and the region accounted for 75 percent of the world's increment of wind capacity installed in 1997. In 1997, Germany's installed wind capacity reached 2,082 megawatts, surpassing that of the United States for the first time. Spain doubled its installed wind capacity in 1997, reaching 421 megawatts, and Denmark's installed wind capacity reached 1,147 megawatts at the end of 1997.

Regional Activity

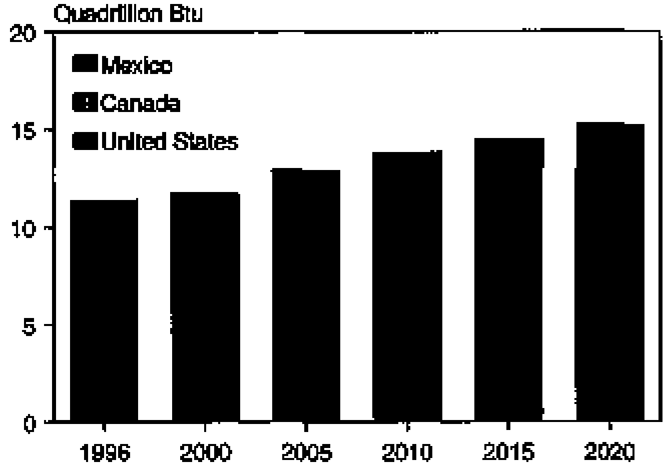
North America

In North America, renewable energy use is projected to expand by 34 percent between 1996 and 2020, reaching a combined total of 15 quadrillion Btu for the United States, Canada, and Mexico (Figure 58). Over the forecast horizon, the renewables share of energy used for electricity generation holds steady for the region at 26 percent.

In the United States, much of the growth in renewable energy use for electricity generation is expected to be in the form of municipal solid waste (MSW), wind, and biomass [8]. The increased use of MSW is attributed mostly to the recovery and use of landfill gas (methane). The projected increase in biomass should be divided between industrial cogeneration and gasification combined-cycle units owned by electricity generators.

The U.S. Department of Interior (DOI) has been working to decommission many hydroelectric dams in the country and to restore rivers to pre-dam states. As part of this effort, the Federal Energy Regulatory Commission (FERC) in 1997 ordered the removal of the 160-year old

Figure 58. Consumption of Hydroelectricity and Other Renewable Energy in North America, 1996-2020



Sources: 1996: Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). Projections: EIA, World Energy Projection System (1999).

Edwards Dam spanning the Kennebec River in Augusta, Maine [9]. Edwards Manufacturing Company—which receives 97 percent of the dam's revenues—and the State of Maine submitted a plan for removing the dam [10]. This was the first time that FERC used its dam-removal authority [11, 12].

DOI also announced an agreement to remove the 12-megawatt Elwha dam near Port Angeles, Washington, but the removal was delayed indefinitely when the U.S. Congress withheld $22 million needed to finance the project [9]. Although some small dams have been removed successfully—such as the 8-foot Jackson Street Dam used to divert water for irrigation in Medford, Oregon, and Roy's Dam on the San Geronimo Creek outside San Francisco, California—efforts to dismantle many of the larger dams slated for removal have been delayed by Congressional action, including four Lower Snake River dams and a partially built Elk Creek dam in Oregon [13].

The installation of wind capacity in the United States has slowed in recent years, but there are signs that wind power production may increase substantially over the next several years. In 1997, the United States added 11 megawatts of wind capacity, but because of the phaseout of older projects, total installed capacity fell to 1,743 megawatts by the end of the year [14, p. 158]. There are, however, plans to add some 800 megawatts of new projects by the end of 1999 throughout the country (Figure 59). There are commercial wind projects under construction or planned for completion in Minnesota, Iowa, California, Colorado, Kansas, Nebraska, New Mexico, New York, Oregon, Texas, Washington, Wisconsin, and Wyoming [15]. Further, a 112.5-megawatt project in

Iowa—which will be the largest single wind farm in the world—is scheduled to begin operating by June 1999.

According to Assembly Bill 1890, the California Energy Commission (CEC) established a program to be funded by a small tax on every kilowatthour of electricity sold to ratepayers of Pacific Gas & Electric, Southern California Edison, and San Diego Gas & Electric from 1998 to 2002. The program will support the renewable energy industry as the State makes the transition to a fully restructured electricity market in which customers can choose among power suppliers [16]. The tax will raise an estimated $540 million for renewables, of which $162 million will be allocated to funding incentives for new wind, geothermal, landfill gas, biomass, digester gas, and small hydroelectric projects. The remaining funds will be used to support existing and emerging renewable electricity generating technologies.

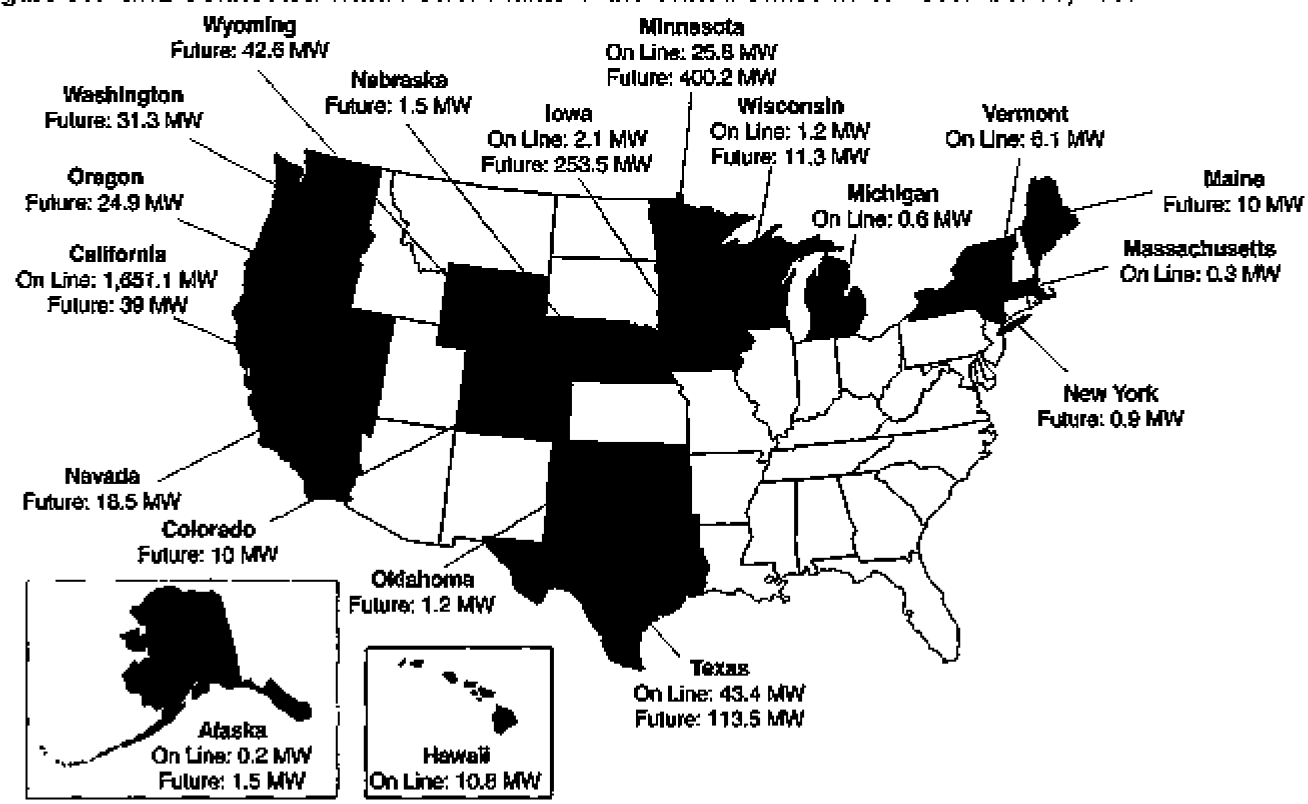
On July 9, 1998, the CEC announced that some 56 proposed projects (representing 600 megawatts of new renewable energy projects) would have the opportunity to receive financial incentives funds of up to 1.5 cents per kilowatthour of electricity generated in the first 5 years of a project's operation [17]. The projects represent 300 megawatts of wind energy, 157 megawatts of geothermal energy, 70 megawatts of landfill gas, 12 megawatts of biomass, and 1 megawatt each of digester gas and small hydropower.

Although there are still plans to add some large-scale hydroelectric power in Canada, the country has begun to focus on developing its wind resources and some small-scale hydroelectric projects. These alternatives to large-scale hydroelectric facilities are gaining favor because they are considered more environmentally friendly and less controversial.

A small-scale hydroelectric initiative that began in Newfoundland in 1992 has had mixed success. Two of the four projects proposed under the initiative—the 15-megawatt Star Lake project and the Rattle Brook project—were commissioned at the end of 1998. In September 1998, however, the province suspended development of the other two projects (the 12-megawatt Northwest River project and the 7-megawatt Southwest River project) pending a comprehensive review of the Canadian province's energy policy [18].

Small hydro development is being reassessed in light of environmental concerns. Another consideration is that Newfoundland plans to develop more than 3.2 gigawatts of large hydro capacity on the Churchill River. Newfoundland & Labrador Hydro plans to construct a new dam and 2.2-gigawatt power project at Gull Island on the Churchill River [19], at an expected cost of about $2.1 billion (U.S.). Several additional hydroelectric projects have been proposed, including the $1.4 billion, 800-megawatt Muskrat Falls development and a

Figure 59. Grid-Connected Wind Power Plants in the United States as of December 31, 1997



Source: International Energy Agency and National Renewable Energy Laboratory, *IEA Wind Energy Annual Report 1997* (Golden, CO, September 1998), p. 159.

1-gigawatt expansion of the 5,428-megawatt Churchill Falls project.

Several wind energy projects currently are being developed in Canada. The first phase of Hydro Québec's largest wind farm—the 100-megawatt Le Nordais project on Québec Province's Gaspé Peninsula—began operating in September 1998 [20]. Seventy-six turbines are now operating, and the remaining 57 are expected to be on line by the end of 1999. When completed, the $103 million (U.S.) project—which is running about 3 years behind schedule—will provide enough power to serve 16,000 homes. In southwest Alberta, the Peigan Nation completed the installation of four 1-megawatt turbines in October 1998 in the first phase of a planned $129 million (U.S.), 101-megawatt grid-connected wind farm [21]. Initially, the project will be used to supply the Peigan Reservation's 3,000 residents. Excess supply will be sold to the provincial Alberta Power Pool.

Another Alberta wind power project was completed by Calgary's Vision Quest Windelectric in November 1997 [22]. The company is marketing its "Greenmax" program to sell emissions-free electricity to residential and commercial customers. Vision Quest installed two 600-kilowatt turbines in southern Alberta—one near Pincher Creek and one near Hill Spring [23]. The company expects to triple its output with additional wind facilities scheduled for completion by mid-1999 [24].

In October 1996, Hydro-Québec announced that it would purchase 10 megawatts of wind power per year over 10 years. In 1997, as part of its 5-year strategic plan, the provincial utility set a target to purchase 20 megawatts of renewable power per year for a 10-year period [25]. In March 1998, a parliamentary commission raised that to 30 megawatts per year. Hydro-Québec is reluctant to commit beyond this level because of concerns about the costs of using wind. The utility estimates that it presently produces power for an average 3 cents per kilowatthour, but the cost of producing wind-generated power has been estimated at twice that amount.

Western Europe

Renewable energy use in Western Europe is projected to grow by almost 70 percent over the 1996 to 2020 forecast period in the *IEO99* reference case. By 2020, 7.6 quadrillion Btu of renewable energy is expected to be consumed for the generation of electricity, representing almost one-fourth of all energy consumed for electricity generation. In 1996, the renewable share of electricity generation in Western Europe was 19 percent. Many countries in the region—including the United Kingdom and Denmark—have set goals for increasing the penetration of renewables in the electric power sector.

Much of the focus on renewables in Western Europe is from individual countries interested in reducing greenhouse gas emissions to levels pledged under the Kyoto Protocol. Although most of the region's hydroelectric resources have already been developed, there is substantial activity in developing alternative renewable energy sources, especially wind power. The European Union announced its intention to invest $11 billion to install 10,000 megawatts of new wind capacity by 2010 [1]. In 1997, Germany's installed wind capacity reached 2,082 megawatts, surpassing that of the United States for the first time; Spain doubled its installed capacity reaching 421 megawatts in a one year period; and Denmark's installed capacity reached 1,146 megawatts, doubling over the past 2.5 years and within 400 megawatts of the country's target of 1,500 megawatts of wind capacity to be installed by 2005 [3, p. 16; 14, pp. 57, 134]. In fact, Western Europe accounted for 75 percent of the world increment of total installed wind capacity in 1997.

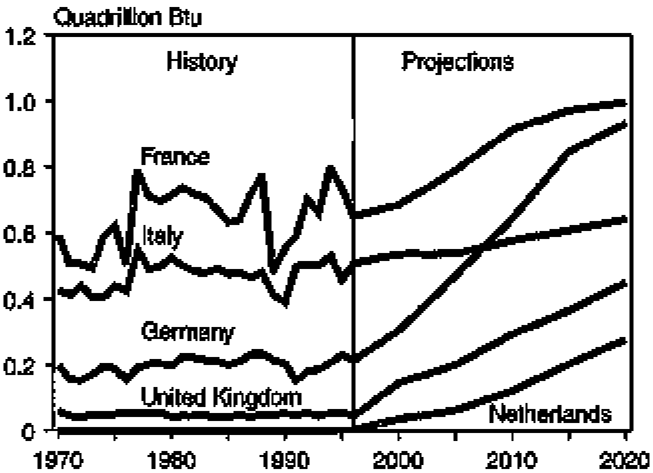
The success of Germany's wind program can be attributed largely to government programs. In January 1991, the country's Electricity Feed Law (EFL) became effective [14, p. 60]. The EFL requires that electric utilities purchase renewable generated electricity from independent power producers at a minimum price of 90 percent of their average electricity rate. In 1999, this will amount to about 10 cents per kilowatthour for wind and solar power, 8.9 cents for small hydroelectric power plants and biomass, and 7.2 cents for large-scale hydroelectric plants [26].

While Germany has not as a nation set wind installation targets, the country has pledged to reduce carbon dioxide emissions by 25 percent in 2005 relative to 1987 levels. Various government actions, such as the EFL and the "250 MW Wind Program," have provided financial incentives to encourage the development of wind generation in Germany. The 250 MW Wind Program provides operators with a subsidy of 3.3 cents or 4.5 cents per kilowatthour, depending on whether the energy is fed into the grid or used by the owner of the wind turbine. Moreover, the states of Lower Saxony and Schleswig-Holstein have published specific wind energy targets. Lower Saxony expects to install 1,000 megawatts of wind energy by 2000 and Schleswig-Holstein 1,200 megawatts by 2010 [14, p. 56]

Germany's largest wind power plant began operating in Denkendorf, Bavaria in September 1998 [27]. The $2.2 million project is constructed with rotors with 1.5 megawatts of installed capacity. The wind farm is expected to generate enough energy to supply the needs of 1,000 households.

The United Kingdom is another European country in which renewable energy sources may enjoy fast-paced growth over the next several years (Figure 60). The government has established a target of generating 10 percent of the country's electricity with renewable energy by 2010 [28]. The development of renewables is supported through Renewables Obligations programs, in which the government pays a premium price for electricity generated from approved renewable energy projects for the duration of each project's contract [29].

Figure 60. Consumption of Hydroelectricity and Other Renewable Energy in Selected Countries of Western Europe, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

The United Kingdom's Non-Fossil Fuel Obligation (NFFO) was created by the Electricity Act of 1989, the legislation behind the privatization of the country's electricity industry. NFFO is a premium price market enablement mechanism intended to encourage the development of electricity generated from renewable resources. Similar schemes have been set up for Scotland (the Scottish Renewables Obligation—SRO) and Northern Ireland (the Northern Ireland NFFO—NI-NFFO).

The difference between the premium price paid for renewable electricity generation and the market price of electricity is financed by the Fossil Fuel Levy, paid by licensed electricity suppliers and passed on to consumers. It is anticipated that prices paid under the Renewables Obligations will converge with market prices under successive Orders, until renewables are able to compete with conventional generation without financial assistance. Beginning in 1990, the United Kingdom issued four NFFOs, two SROs, and two NI-NFFOs. A fifth NFFO and a third SRO were issued in 1998, and in November 1998 the Energy and Industry Ministry announced that 261 projects had been awarded, totaling 1,177 megawatts of installed capacity. Most of the projects are for landfill gas, but municipal and industrial waste, wind, and small-scale hydroelectric projects were also approved [30].

Because hydroelectric and other renewable resources in Italy are well established relative to those in other Western European countries, the *IEO99* reference case projects growth of only about 1.0 percent per year between 1996 and 2020. Italy ranks fourth in terms of renewables consumption in Europe; only Norway, Sweden, and France consume more renewable energy [31, pp. 190 and 194]. The bulk of Italy's renewable energy use is in the form of hydroelectricity and, to a much smaller extent, geothermal power [14, p. 79]. Over the past several decades, it has become increasingly difficult to find new sources for hydroelectric power plants and new geothermal resources. The Italian government has begun to look at ways to develop its wind energy resources, but commitments so far have been modest. In Italy's 1998 National Energy Plan, the government set a target to install 300 megawatts of wind energy by 2000—only a fraction of the country's present 66,000 megawatts of total installed generating capacity [14, p. 82].

Spain has experienced fast-paced growth in wind energy installations in recent years. Almost 100 megawatts of wind capacity was installed in the country in 1996, doubling to 421 megawatts in 1997, with 477 wind turbines installed at 14 wind farms [13, p. 134]. Although the pace of installation slowed, nearly 150 megawatts were added in 1998 [32]. Spanish regional wind energy programs have established targets for wind power increments that may add as much as 8,000 megawatts of installed capacity by 2012 [13, p. 134].

Several additional wind projects were either planned or under construction in Western Europe in 1998. In Norway, energy producer Norsk Miljo Energi Sor (NMES) announced plans to construct the country's largest wind project, a 300-megawatt wind plant in the northern part of the country [33]. NMES also has plans to construct a second 300-megawatt wind facility in Vest-Agder. In Sweden, the 220-kilowatt Svante turbine located off the Coast of Nogersund began operating in 1998 [3, p. 135]. Work on the second generation of large wind turbines was begun in 1993 at the Naesudden site, where a 3-megawatt plant is being constructed. Sydkraft announced plans to build a 7.2-megawatt wind project on the island of Gipsön, outside Landskrona, for an estimated $7.7 million.

Asia

The economic downturn in southeast Asia will no doubt have some negative impact on near-term development of renewable projects; however, long-term projects begun before the crisis, such as China's Three Gorges Dam, have continued for the most part on schedule. Developing Asia remains one place where large-scale hydroelectric projects are still being pursued, despite the controversy that usually surrounds them. China has announced plans to construct more than 20 hydroelectric projects between 1998 and 2020, both to generate much-needed electricity and to control flooding. A substantial number of the projects will have installed capacities exceeding 3.3 gigawatts.

Developing Asia

China

The flood damage that devastated China in 1998 is estimated to total over $36 billion (U.S.) with more than 3,000 deaths and 5 million homes destroyed [34]. The Yangtze River valley was hit with eight flood crests over a 2-month period, and the flooding has strengthened desires to protect the population with hydroelectric dams along the river. By 2010, China plans to have installed flood control dams with more than 100 gigawatts of hydroelectric power, providing an estimated 30 percent of the country's electricity [35].

China currently has 19 operable hydroelectric projects with installed capacities greater than 1 gigawatt. Hydroelectric power projects now under construction will have an estimated total generating capacity of 32 gigawatts. Other proposals for large-scale hydroelectric projects in China include one 12-gigawatt project and one 5.2-gigawatt project on the Jinsha River (a tributary of the Yangtze River); one 3.3-gigawatt project on the Dadu River (also a tributary of the Yangtze); and more than 20 other power projects planned for the Yalong River, the largest of which—the Jinping Hydroelectric Power Station—has a proposed capacity of 3.6 gigawatts [36, 37].

The State Power Corporation of China (SPC) has announced that the country will focus on developing large-scale hydroelectric projects [35]. In September, the SPC announced plans to invest $7.23 billion to construct five hydroelectric projects by 2010 [38], including the 1.5-gigawatt Gongboxia project, the 3.72-gigawatt Laxiwa project, the 5.4-gigawatt Longtan project, the 4.2-gigawatt Xiaowan project, and the 1.5-gigawatt Sanbanxi project.

Construction on the world's largest hydroelectric project, the 18.2-gigawatt Three Gorges Dam, entered Phase 2 of a three-phase process in 1998 [39]. Although construction on the dam was temporarily suspended in August because of the extensive flooding along the Yangtze, Phase 2 is still scheduled for completion in 2003, when the dam will start generating electricity. Phase 3 should end in 2009 with the beginning of full power generation. About $3.7 billion has already been spent on construction of Three Gorges Dam, including temporary diversion of the Yangtze and draining of the building site so that construction of the dam can continue. Upon completion, the project will extend 1.4 miles across the Yangtze and will be 607 feet tall, creating a 370-mile-long reservoir, which will allow shipping through the central Yangtze to increase from 10 million to 50 million tons annually. The official Chinese estimate for the cost of the entire project is $25 billion.

Three Gorges Dam has been the subject of much controversy. Critics say that water pollution along the Yangtze will double as the dam traps more than 50 kinds of pollutants from mining operations, factories, and human settlements that used to be washed out to sea by the strong currents of the river [39]. Some believe that the heavy silt in the river will deposit at the upstream end of the dam and clog the major river channels of Chongqing. An estimated 1.1 million to 1.9 million people will have to be resettled before the reservoir is created; around 1,300 archaeological sites will have to be moved or flooded; and the habitats of several endangered species and rare plants will be jeopardized. In 1996, the U.S. Export-Import Bank declined to grant guarantees for U.S. companies hoping to work on Three Gorges Dam, citing the potential environmental problems; however, Export-Import banks in Canada and Germany have supported financing efforts for companies based in those countries, such as General Electric-Canada and Siemens.

There are many additional large-scale hydroelectric projects underway or planned in China. In 1998, China began trial operations of its largest generating unit to date—the first of six generators at the $3.4 billion Ertan hydroelectric power plant [40]. Located at Panzhihua City on the Yalong River, a tributary of the Yangtze's upper reaches, Ertan is Asia's second tallest dam. The project is expected to help ease the electricity shortage in Sichuan province, as well as to stem flooding from the upper reaches of the Yangtze. The second generator at the Ertan dam in southwestern Sichuan province started operating in November 1998. Ertan's six generating units, each with a capacity of 550 megawatts, should be completed by the end of 1999, making the 3,300 megawatt power plant China's largest electricity supplier. Construction on the project began in 1991. The project, unlike Three Gorges, has benefitted from support from the World Bank. Since May 1, 1998, the dam has held back about 40 percent of the Yalong's flood waters to ease the water flow on the middle and lower reaches of the Yangtze.

The Tianshengqiao power station in Guangxi Zhuang Autonomous Region in southern China was scheduled to begin generating power by the end of 1998 [35]. Construction is also underway on a pumped-storage station in Tibet at Yamzho Yumco Lake. The Tibetan station is being constructed at an elevation of 12,000 to 15,000 feet, the highest project in the world. In 1997, China announced plans to build a hydroelectric project along Tibet's Brahmapoutre river, near the Yalutsan mountain, which could generate a proposed 40 gigawatthours per year, double the amount projected for the Three Gorges Dam [41].

Until recently, China had developed little of its renewable energy resources beyond its hydroelectric power. By 1995, China had installed only 14 wind power farms with a combined capacity of 50 megawatts. Further, installed photovoltaic, geothermal, and ocean tidal power stations provided only 6, 32, and 11 megawatts of capacity, respectively [42].

At the start of 1996, more than 72 million people in rural areas still were not connected to the national electricity grid. Electricity demand for this part of the population is expected to be satisfied by developing new energy technologies, because grid expansion is too slow and expensive. More than 140,000 mini wind turbine units (60 to 200 watts) operate in China, of which more than 110,000 are located in Inner Mongolia. The annual production of mini wind turbines exceeds 21,000 units in the region. Chinese government forecasters estimate that the total installed capacity of mini wind turbines will be 30 megawatts in 2000 and 140 megawatts in 2020, with total power generation of 90 and 450 gigawatthours, respectively. In appropriate areas, decentralized wind power stations over 10 megawatts will be built and hybrid wind/diesel or wind/solar systems will be developed.

By the end of 1998, 71 Chinese wind turbines with capacities of 500 to 600 kilowatts were expected to be installed [43]. China is building four wind farms with a combined 190 megawatts capacity, which should be completed by mid-1999 [44]. The largest of the plants is a 100- megawatt farm to be built in Huitengxile, in the northern province of Inner Mongolia. Other projects include a 50-megawatt facility at Zhangbein in northern China's Hebei province; a 20-megawatt facility at Pingtan in southeast China's Fujian province; and a 20-megawatt facility at Chonming Island in Shanghai, east China. The projects are being funded with loans of between $65 and $120 million from the World Bank and a $10 million grant from the Global Environmental Facility.

The 20-megawatt facility at Shanghai's Chonming Island is being installed as part of the local government's plans to develop wind power in the city to reduce reliance on coal-fired electricity [45]. The farm, being built at Dongwangsha, will consist of 34 wind turbines. Energy demand in Shanghai has grown rapidly, as the city's economy has grown by 10 percent annually in recent years and authorities are running out of suitable sites for new thermal power stations. Shanghai is expected to have 12,000 megawatts of thermal generating capacity by 2000.

China also has plans to develop more of its geothermal heat resources to generate power [46]. The country plans to build medium-sized geothermal power stations in the southwestern part of China. The stations are to be developed in Tibet and western parts of Yunnan and Sichuan provinces by 2020. Priority is to be given to geothermal resources with reservoir temperatures above 200 degrees centigrade in Tibet's Yangbajing.

India

Similarly to China, India has begun focusing on large-scale hydroelectric projects to ease electricity shortages in the country. So far, 12 large-scale projects have been approved, all to be completed by 2002 [7]. The projects are expected to add a combined 3.7 gigawatts of installed hydroelectric capacity. In addition, 5.81 gigawatts of capacity are to be added by new state-sector projects and 350 megawatts by the private sector.

National Hydroelectric Power Corporation will construct five projects in Himachal Pradesh State and one each in Manipur and Sikkim. The Central Electricity Authority has been asked to give technical and economic approval to two 800-megawatt projects in Himachal: Parbaht Stage 2 and Kol Dam. India's Energy Development Company Ltd. expects to commission its 9-megawatt Harangi Dam in April 1999. This facility is expected to generate about 36 million kilowatthours of electricity per year. In the northern states of Jammu and Kasmir, construction began in October 1998 on a 450-megawatt hydroelectric project on the Chinab River [47]. When completed, the facility is expected to provide 2,600 megawatthours of power per year.

The Indian government has begun a policy to promote development of hydroelectric power. The government plans to introduce a tariff subsidy to support the development of hydroelectric power in an effort to improve the nation's energy mix [47]. At present, 78 percent of India's electricity is fueled by coal and 13 percent by hydroelectricity and other renewables, with natural gas, oil, and nuclear contributing the remainder. The tariff is expected to raise an estimated $714 million annually. Other policy decisions provide that hydroelectric facilities with installed capacity up to 250 megawatts will not require technical or economic approval from the Central Electricity Authority, which at present scrutinizes every proposed project that exceeds 100 megawatts.

In 1992, at the start of the eighth Five-Year Plan, India's installed capacity of small-scale hydroelectric projects was 93 megawatts. By the beginning of 1997, there were 216 such projects installed, with a combined capacity of 155 megawatts. Work is in progress on 208 projects that will provide 230 megawatts of installed capacity. India's federal Ministry of Non-conventional Energy Sources (MNES) is promoting small-scale hydroelectric projects of up to 3 megawatts to develop remote rural areas. MNES conducted a nationwide survey and identified the potential for development of a combined 2,040 megawatts in 25 states and outlying islands [48]. Sites with a potential of about 600 megawatts have been offered by states for commercial development.

To further accelerate the exploitation of the small hydropower potential and to promote their commercialization, MNES has charted out several measures. Some of the main objectives and activities being undertaken during the ninth Five-Year Plan are small hydro resource assessment; encouragement to commercial small hydro projects; renovation and modernization of old small hydro projects; special incentive packages for northeastern states to exploit small hydro potential; upgrading of water mills; and intensification of industry-based research and development.

Although the development of wind power in India was among the world's largest in 1995 and 1996, the market stagnated in 1997, mostly because the Asian economic slowdown made it difficult to secure financing for new development [1]. Further, India's wind project have performed badly for a number of reasons, including a vast overestimation of wind resources in certain areas, poor project design and operation, and problems with the utility grid. To improve the record of wind projects, the Indian government plans to offer tax credits for electricity generated from wind projects, rather than merely offering the incentives to companies investing in their construction. A number of wind projects currently are under construction in India. Lagerwey Windturbine of the Netherlands is supplying 80 wind turbines for a 20-megawatt wind project in Puthlur, approximately 190 miles south of Hyderabad [49]. In June 1998, Lagerwey commissioned a 20-megawatt Indian facility located in the state of Tamil Nadu.

Other Developing Asia

Several hydroelectric power projects were introduced in countries of developing Asia other than India and China in 1998. In Myanmar (formerly Burma), the country's second largest hydroelectric project will be built, the 280-megawatt Paung Laung plant [50]. Upon completion (scheduled for 2002), the facility will raise Myanmar's generating capacity by 30 percent [51].

Indonesia completed its largest hydroelectric plant in April 1998, the 1,000-megawatt Cirata plant in West Java [52]. The plant was constructed with $852 million in funding from the World Bank and Australia. Unfortunately, the country's economic problems mean that the new capacity is not needed. The connection of the Cirata plant to the Java-Bali grid will bring total excess capacity to 9,300 megawatts. Java-Bali's generating capacity is estimated at 15,000 megawatts, but peak load demand is only about 9,500 megawatts.

Despite lingering economic and political problems in Indonesia, Solarex—the business unit of Amoco/Enron Solar—expects to complete its $25 million solar rural electrification project [53]. The project, initiated in June 1998 in Jakarta, involves installing 36,400 solar systems throughout Indonesia. By the end of September 1998, more than 21,000 units had been installed, with the remaining 15,400 units scheduled to become operational by the end of 1999. Currently only 31 percent of all households in Indonesia have access to the national power grid, and the aim of the Solarex project is to bring electricity to those people who live in areas where national grid expansions are not expected within the next 5 years.

Construction on the $220 million Houay Ho hydroelectric project in Laos is nearly complete; however, the continuing economic troubles in Thailand—the largest expected purchaser of Houay Ho's output—make the facility's future somewhat uncertain. In September 1998, Thailand's state power company, the Electricity Generating Authority of Thailand (EGAT), agreed to a slight adjustment in the established tariff pricing structure for its power purchase from Houay Ho [54]. EGAT agreed to raise the ratio of U.S. dollars in the tariff payment from 50 percent at present to 55 percent. The Houay Ho consortium of owners wanted EGAT to pay for the electricity in U.S. dollars exclusively because of the weakened Thai currency, the baht. The 30-year power sales to EGAT are contracted to begin in September 1999.

Industrial Asia

The three countries that comprise industrial Asia—Australia, Japan, and New Zealand—have different levels of renewable energy penetration. In New Zealand, more than 80 percent of electricity generation is attributed to hydroelectricity and other renewables. Both Japan and Australia generate about 9 percent of their electricity with renewables. In Australia, virtually all renewable energy is in the form of hydroelectricity. Of the 14.8 billion kilowatthours of renewable energy consumed in Australia in 1996, only 0.03 billion kilowatthours was contributed by geothermal, wind, and solar. In contrast, Japan consumed 3.4 billion kilowatthours of electricity generated from geothermal, wind, and solar energy.

All three countries have begun construction on renewable projects other than hydroelectricity. In New Zealand, Tararua Wind Power finally began construction work on the country's first large wind farm, a 31.7-megawatt project located near Palmerston North, North Island. The project has been in planning stages since the end of 1995. Initially, it will consist of 48 660-kilowatt turbines, although the company could expand the project to 67 megawatts in the future. So far, the only other wind farm operating in New Zealand is a 3.5-megawatt facility that was completed in 1996 [55].

Growing interest in wind power in New Zealand has also resulted in a proposal by Shell International Renewables to develop offshore wind farms [56]. Shell believes that its expertise in offshore oil projects could be applied to the development of offshore wind. There are also hopes that offshore wind power would stop complaints about potential noise pollution, which have hindered wind power development in New Zealand. Opposition by residents of Makara, New Zealand, to a planned wind project because of noise concerns forced the Electricity Corporation of New Zealand to scale back the project.

There has also been some growth in Australia's wind power installations. The country's largest wind farm—the Crookwell plant in New South Wales—was commissioned at the end of August 1998 [57]. The 4.8-megawatt facility consists of eight 600-kilowatt turbines. Electricity generated from the plant will be sold to Great Southern Energy under a 20-year contract and marketed to customers who will pay a premium price for the "green" energy.

According to the International Energy Agency, at the end of 1996 Japan's installed wind capacity totaled 14 megawatts—less than 2 percent of Asia's 891 megawatts of total installed wind power capacity. Currently, the Japanese trading company, Tomen, is installing Japan's largest wind farm in Tomamae, Hokkaido, in northern Japan. The 20-megawatt facility will more than double the installed wind capacity in Japan. It will consist of 20 wind power generators, each with a capacity of 1,000 kilowatts [58]. The $33 million project is expected to begin operating in October 1999. Electricity will be sold to Hokkaido Electric Power Company at an average cost of 8.5 cents per kilowatthour for a 17-year period, representing the first long-term commercial contract that a Japanese electric power company has signed for wind-generated electricity.

Central and South America

Many countries of Central and South America rely heavily on hydroelectricity for electricity generation. In Brazil—which accounts for about 40 percent of the region's total installed capacity—86 percent of the 59 gigawatts of total installed capacity in 1996 consisted of hydropower. Hydroelectric dams also account for 50 percent or more of the total installed generating capacity in Chile, Colombia, Paraguay, Peru, and Venezuela.

Although many of the region's hydroelectric resources have been developed, there are still plans to add substantial capacity over the forecast period, despite efforts in many Central and South American countries to diversify the fuel mix for electricity. Because dependence on hydropower can lead to brownouts and blackouts during times of drought, Brazil has been attempting to construct a natural gas infrastructure to bring gas from Bolivia and Argentina to fuel new gas-fired capacity. Standard & Poor's DRI has estimated that the natural gas share of total generating capacity in Brazil will climb from 1 percent in 1995 to 21 percent by 2020, almost entirely at the expense of hydropower [59, pp. 62-63].

Brazil still has more hydroelectric projects under construction or planned for future installation than any other country in the Central and South America region. In September 1997, the final turbine was installed in the 3.0-gigawatt Xingó hydroelectric power facility on the São Francisco River at Piranhas [60]. The $3.1 billion project accounts for 25 percent of the installed capacity in northeast Brazil. Other large hydroelectric facilities currently under construction in Brazil include the 1.45-gigawatt Itá hydroelectric plant, which is scheduled for completion in mid-2000, and the 1.14-gigawatt Machadinho hydroelectric plant, which is scheduled for completion in 2003; both facilities are located on the Uruguay River. Construction on the $1 billion, 950-megawatt Lajeado dam near Palmas, Brazil, began in May 1998, and it should become operational by the end of 2003. Finally, there are also plans to expand the 12.6-gigawatt Itaipu project held jointly between Brazil and Paraguay [61]. The facility is to be expanded by 1,400 megawatts at a cost of about $200 million.

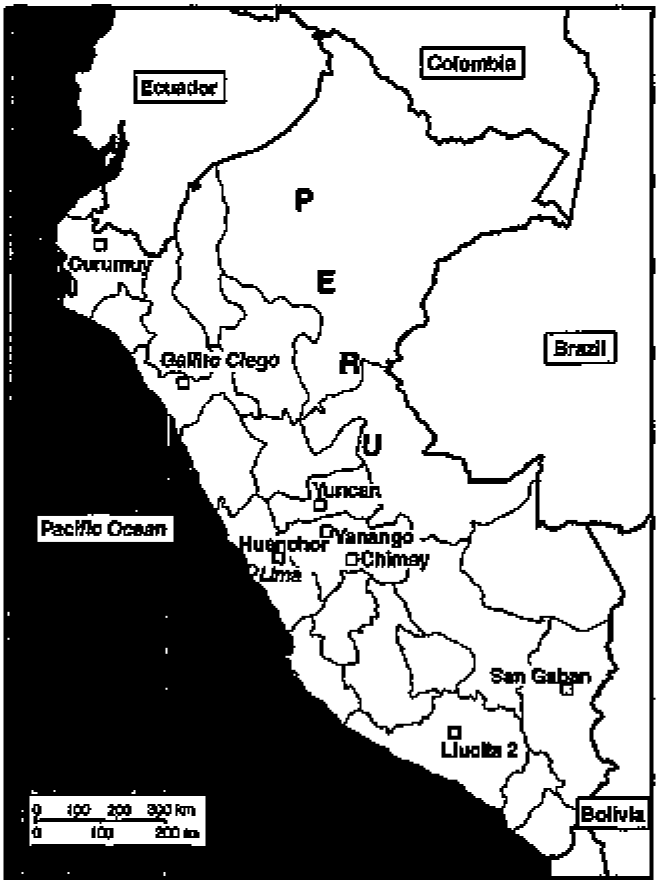
In Argentina, plans to add three 155-megawatt turbines, in addition to the expansion completed in 1998, will bring the Yacyreta hydroelectric plant to 3.1 gigawatts capacity [59, pp. 32-34]. The additional capacity is to be used to generate exports for Brazil and an agreement to construct a 291-mile transmission line for this purpose was finalized in 1998.

In Chile, construction began on the $500 million Ralco hydroelectric project on the BioBio River in 1998 [62]. The Spanish electric company, Endesa, had planned to bring the 570-megawatt project into operation by 2002, but work was suspended in October 1998 when the company was unable to reach an agreement with the indigenous Pehuenche people who must be relocated if the project is to be completed. Ralco has also been the subject of protest from environmental groups because of its potential environmental damage, as well as the issue of displacing the Pehuenche [63].

Peru has recently had a surge in hydroelectric projects [64]. Two plants were completed in the northwestern part of the country in 1997—the 12-megawatt Curumuy and the 34-megawatt Gallito Ciego. Six other projects are currently under construction (Figure 61). All the projects are relatively small, with installed capacities ranging between 16 and 142 megawatts.

In 1998, a number of renewable energy projects beyond hydroelectricity were begun. In Argentina, the World Bank issued a solicitation for a rural renewable energy program as part of its "Renewable Energy in Rural Market Project" [65]. The project, which is attempting to provide solar electricity to more than 100,000 households,

Figure 61. Hydroelectric Plants in Peru Completed and Under Construction, 1998



Source: *Financial Times: Power in Latin America*, Vol. 40 (October 1998).

also has several initiatives that include other renewable energy sources. One initiative envisions the installation of renewable energy power systems (solar, wind, or hydro) with capacities ranging from 3 kilowatts to 10 kilowatts, along with diesel generators to provide electricity to some 5,900 households that are less decentralized than those slated for solar systems. A second element will cover the installation of 2,900 small renewable systems to generate power for public facilities, such as schools and police stations. And in a third element, two pilot community wind systems will be installed. The program is expected to cost $187 million. Of that amount, $46 million will be provided by a World Bank loan, $14 million will come from a grant from the Bank's Global Environmental Facility, and the remainder will come from provincial governments and other sources.

In a disappointment to environmentalists, Argentine President Carlos Menem signed a decree in 1998 annulling key parts of a bill that would have provided a tax incentive to wind and solar power developers [66]. The proposed legislation would have given wind and solar energy generators 1 cent for each kilowatthour of electric power generated from their projects [67].

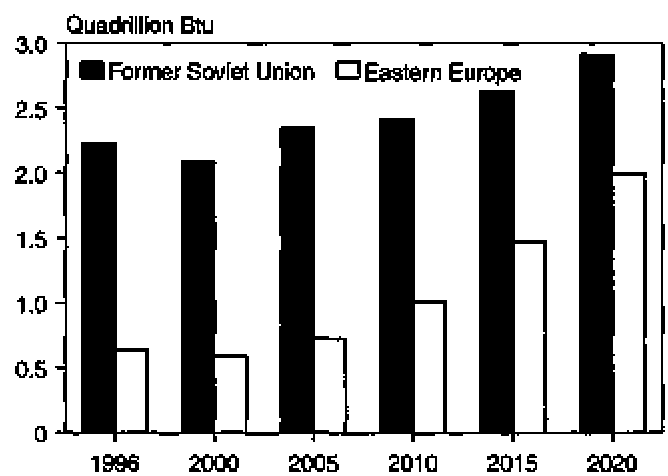
There are several alternative renewable energy projects under way in Costa Rica. The country recently built a 20-megawatt wind farm at Guanacasta and is studying the effects of the wind farm on the national grid [67]. In addition, the Inter-American Development Bank successfully completed financing for a 27.5-megawatt geothermal plant, the first private-sector energy project in Costa Rica to be built on the basis of a build-own-transfer contract resulting from a private bid [68].

Eastern Europe and the Former Soviet Union

Development of renewable resources in Eastern Europe and the former Soviet Union (EE/FSU) remains limited primarily to expansion or refurbishment of existing hydroelectric units, especially in the FSU, where economic troubles have persisted since the Soviet collapse of the early 1990s, worsening even more with the devaluation of the ruble in the summer of 1998. In the *IEO99 reference case*, energy generated from hydroelectricity and other renewable resources grows by only 1.1 percent per year between 1996 and 2020, rising modestly from 2.2 to 2.9 quadrillion Btu (Figure 62).

The economies of the countries of Eastern Europe have fared much better than those of the FSU. As a result, the prospects for renewables are somewhat better. Regional gross domestic product returned to positive growth in 1994, averaging 4.8 percent annually until 1997, when growth fell to 3.3 percent [69, p. 37]. Much of the increased energy use in Eastern Europe is expected to be in the form of natural gas use to displace coal and nuclear generation, but systematic growth of hydroelectricity is also expected in countries such as Slovenia and

Figure 62. Consumption of Hydroelectricity and Other Renewable Energy in Eastern Europe and the Former Soviet Union, 1996-2020



Sources: **1996:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

the former Yugoslavian Republics of Croatia, Serbia-Montenegro, and Macedonia, where undeveloped hydropower potential still exists [69, pp. 41, 47, 49]. Renewable energy use in Eastern Europe grows by 4.9 percent per year over the projection period, tripling to 2.0 quadrillion Btu in 2020 (Figure 62).

Several hydroelectric projects are being started in Macedonia. In May 1998, the World Bank approved a $35 million loan for the country's power company, Elektrostopanstvo Na Makedonija (ESM), which will be used for three electric power sector projects [70]. The most important is a $26 million upgrade of six hydroelectric facilities: Vrutok, Raven, Vrben, Tikves, Spilje, and Globocica. The others involve upgrades to the dispatch center of the national power system ($5.5 million) and repair of ESM's electricity distribution system ($3.5 million). Macedonia has also secured an $80 million loan from China for the new Kozjak hydroelectric plant, which was scheduled for completion in December 1998 [71]. This is the largest single investment in southeastern Europe to be supported by Chinese financial institutions.

The Yugoslav Republic of Montenegro also has plans to begin a number of hydroelectric projects. The country has plans to restart construction on the 450-megawatt Buk Bijela hydroelectric facility, which was begun in the early 1970s but suspended in 1974 [72]. The project would be a joint venture between Montenegro's Elektroprivreda Crne Gore/Montenegro and the Bosnian Srpska Republic's Elektroprivreda Rebublike Srpske. The plant, when completed, could supply 1,100 gigawatthours of electricity per year, with 400 gigawatthours going to Montenegro and the rest to Srpska. Montenegro also has plans to construct four or five hydroelectric plants on the Moraca River [73]. Final tenders for work on the 195-megawatt Andrijevo, 55.5-megawatt Raslovici, 55.5-megawatt Milunovici, and 55.5-megawatt Zlatica hydroelectric projects were to be issued by the end of 1998, with construction scheduled to begin in mid-1999.

In Slovenia, a number of projects are underway to modernize existing hydroelectric facilities. For the Drava hydroelectric power project, $35 million is being spent to refurbish and expand the facility [74]. Similarly, $21 million is being spent to rehabilitate the Soca hydroelectric power plant. There are also plans to construct two additional hydroelectric plants on the Soca River [75]. The 41-megawatt Doblar 2 and 20-megawatt Plave 2 should be completed by 2001, at an expected cost of $111 million. They are being designed as peak-demand plants to support the two existing stations on the Soca.

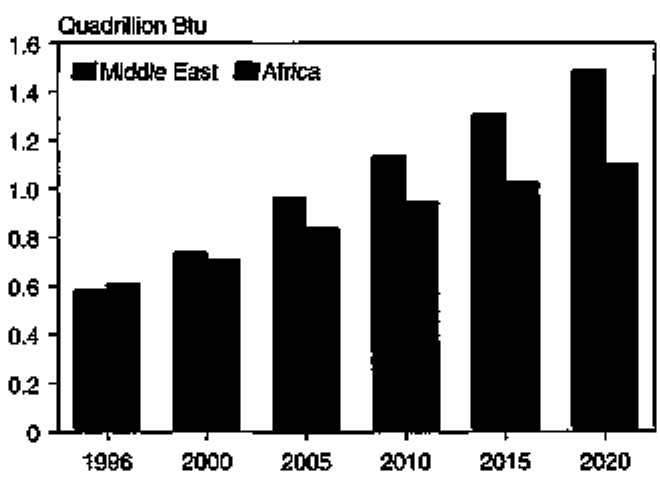
Mini-hydroelectric power stations are being developed in Bosnia and Herzegovina to replace infrastructure damaged during the Bosnian War. A 2-megawatt hydroelectric plant in Modrac that began operating in September 1998 [76] was the third mini-hydro plant completed since the Dayton Peace Accord came into effect. The $1.9 million project was financed by Elektroprivreda Bosne I Hercegovine and Sarajevo's Vodorivreda Bosne I Hercegovine.

Development of renewable energy resources beyond hydroelectricity remains small in Eastern Europe. A German registered company, Baltic Energy GmbH, has presented a planning application to Estonian authorities seeking to build 17 1.5-megawatt wind power stations on the island of Saaremaa, Estonia's largest offshore island [77]. The project, which caries an estimated cost of $25 million, aims to supply 30 percent of the island's total annual electricity requirement. Baltic Energy hopes to arrange financing for 75 percent of the costs. The company is interested in undertaking the investment in cooperation with local investors and has invited a number of Estonian banks and energy enterprises to take a 25-percent capital holding in the venture.

Africa and the Middle East

In Africa and the Middle East, only hydroelectric power has contributed to any significant development of grid-connected renewable energy sources. In many African countries, hydroelectricity's share of total installed electric capacity is quite high. For instance, in the Congo (Kinshasa), Ethiopia, Ivory Cost, Mozambique, and Zambia virtually all on-grid electricity generation comes from hydropower. In 1996, 0.6 quadrillion Btu of hydroelectricity and other renewables were consumed in Africa, and by 2020 that amount is projected to grow to 1.2 quadrillion Btu (Figure 63).

Figure 63. Consumption of Hydroelectricity and Other Renewable Energy in Africa and the Middle East, 1996-2020



Sources: **1996**: Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections**: EIA, World Energy Projection System (1999).

In the *IEO99* reference case, renewable energy use in the Middle East is projected to grow from 0.6 quadrillion Btu to 1.5 quadrillion Btu over the projection period. In this region, only Turkey has a sizable amount of hydroelectric capacity, with about half the country's electricity needs being met by hydropower. Although Turkey has been aggressively developing its natural-gas-fired generation, numerous hydroelectric projects are currently under development—including the $32 billion Greater Anatolia Dam Project (GAP), which is projected to increase electricity generation by one-third by 2010 [78]. When completed, the GAP project will consist of 21 dams, 19 hydroelectric plants, and a network of tunnels and irrigation canals [79]. An expected 27,000 gigawatthours should be generated once the project is completed.

The Turkish Ministry of Energy and Natural Resources has plans to install a total of 113 hydroelectric units to meet the country's growing demand for electricity—along with 33 lignite-fired projects, 27 gas-fired, 12 coal-fired, and 2 nuclear. The total investment needed to finance these electricity projects has been estimated at between $35 and $50 billion over the next decade [79]. Further, according to Turkish Energy Minister Cumhur Ersumer, in June 1998 the country had reached agreement with companies in the United States, Canada, Russia, Austria, and France for the construction of 21 turnkey hydroelectric power dams. The Netherlands has also proposed developing 5 turnkey hydroelectric facilities on the Firat, Isparta, Antalya, Aras, and Dicle rivers.

Several announcements were made in 1998 regarding the development of Ethiopia's hydroelectric resources. In 1996, the country had only 372 megawatts of hydropower capacity, despite substantial hydroelectric potential [31]. In March, the country announced that work on seven hydropower dams was expected to be completed over the next 5 years, bringing total hydroelectric capacity to 713 megawatts [80]. The 72-megawatt Tisabay hydropower dam—located at the source of the Blue Nile—has already been completed, and a second 73-megawatt unit (Tisabay II) is expected to be operational in 2000. The 73-megawatt Finchaa IV unit in the west is expected to be completed by 2001, as is the 103-megawatt Gilgel-Gibe unit, which was financed with a $300 million World Bank loan.

Studies of hydroelectric potential on Ethiopia's Tekeze, Gojeb, and Tisabay rivers suggest that the rivers could supply 523 megawatts of generating capacity [80]. Tenders are expected for work on the 203-megawatt Tekeze dam project—which will be the biggest in Ethiopia—and a 154-megawatt hydropower plant at the Gojeb dam. Two Norwegian companies, Nor-Plan and NorConsult, are to draw up a hydropower generation study for the Ethiopian Electric Light & Power Corporation. The 6-month study will examine the hydroelectric potential of the Genalle, Baro, and Geba river basins.

Ethiopia also made some advances in geothermal installation in 1998. A 35-megawatt geothermal plant in the country's Rift Valley became operational in September [81], more than doubling the installed geothermal and other renewable energy capacity in Ethiopia, from 30 megawatts in 1996.

Although the penetration of renewable sources to grid-connected systems in Africa remains small, there are a number of projects aimed at bringing dispersed renewables to rural parts of the country. For instance, in October 1998, Shell International Renewables Ltd. and South Africa's state utility, Eskom, announced plans to invest $30 million in the development of solar power in rural South Africa over the next 3 years [82]. The 50-50 venture will provide standalone solar power units to as many as 50,000 homes currently without electricity, at a cost of about $8 per month—about the same amount consumers in South Africa currently spend on less effective, unsustainable fuels [83]. The power units are capable of fueling three low-voltage lamps and a small television or radio for 4 hours per day and will cost about $800 to manufacture and install. Shell has estimated that it might take as long as 9 years to recover the $30 million investment, but that the project could supply some 25 megawatts of power to regions that are currently not able to access the nation's electric power grid.

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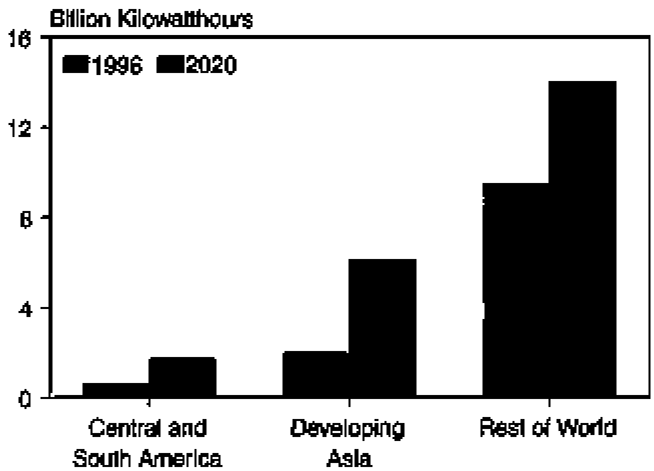
Electricity

Electricity continues to be the most rapidly growing form of energy consumption in the IEO99 projections. The strongest long-term growth in electricity consumption is projected for the developing countries of Asia.

Long-term growth in electricity consumption is expected to be strongest in the developing economies of Asia, followed by Central and South America (Figure 64). In the reference case for the *International Energy Outlook 1999* (*IEO99*), the projected growth rates for electricity consumption in the developing Asian nations average nearly 5 percent per year from 1996 to 2020 (Table 17). Electricity consumption growth in Central and South America is projected to exceed 4 percent between 1996 and 2020. The projected increases in electricity use are based on expectations of rapid population and economic growth, greater industrialization, and more widespread household electrification. Developing nations are expected to account for 43 percent of the world's total electricity consumption in 2020, compared with only 28 percent in 1996. With much of the world population today still having only limited access to electricity, a significant portion of the future growth in electricity use will result from the connection of more of the population to the electricity grid.

Figure 64. World Electricity Consumption by Region, 1996 and 2020



Sources: **1996:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

In future years, electricity will continue to be the most rapidly growing form of energy consumption, rising from 12 trillion kilowatthours in 1996 to almost 22 trillion kilowatthours in 2020 in the *IEO99* reference case. Although demand for electricity, like other forms of energy, has been affected by recent global economic and financial problems, an economic turnaround is expected in a year or two, accompanied by a resumption of earlier trends in demand growth.

Collapsing financial markets and falling currencies can affect energy demand in several ways. For countries that are net importers of energy, a debased currency means that more of the currency must be expended on energy imports, as well as on other goods and services. If a country's financial markets fail, economic growth and energy demand growth may be slowed as investments in development projects (including energy projects) become more risky and capital formation becomes more difficult. Corrective measures, such as raising domestic interest rates in order to restore stability to currency values and financial markets, may at the same time reduce economic growth, slow the growth of long-term investment, and depress aggregate energy demand.

The countries most immediately affected by the economic crisis that originated in Asia in mid-1997—Thailand, Malaysia, South Korea, Indonesia, and the Philippines—have undertaken various economic policies to restore economic growth, and there have been some positive signs that their economies are beginning to turn around. China and India have also been affected by the crisis, although not nearly as much. The *IEO99* projections of electricity demand growth for these regions are substantially lower than last year's projections out to the year 2000, but less so out to 2005 and hardly at all for 2020.

Annual growth in electricity consumption for the industrialized economies is expected to average 1.6 percent between 1996 and 2020, with continuing penetration of electric equipment in the end-use sectors counterbalanced by slowing population growth and higher energy efficiencies. Economic growth in the industrial economies has also been affected by the Asian crisis, largely through a slowdown in exports to Asian markets. In 1998, as a result of growing concerns that Asian economic problems had begun to affect the industrial world, several central banks reduced interest rates and eased monetary policies.

Japan, the largest economy in Asia and second largest in the world, continues to be a significant source of

Table 17. World Net Electricity Consumption by Region, 1990-2020
(Billion Kilowatthours)

Region	History		Projections					
	1990	1996	2000	2005	2010	2015	2020	Average Annual Percent Change, 1996-2020
Industrialized Countries	**6,248**	**7,194**	**7,529**	**8,298**	**9,001**	**9,749**	**10,485**	**1.6**
United States	2,713	3,243	3,333	3,585	3,843	4,113	4,345	1.2
EE/FSU	**1,908**	**1,535**	**1,396**	**1,536**	**1,673**	**1,813**	**1,965**	**1.0**
Developing Countries	**2,274**	**3,324**	**3,895**	**5,033**	**6,282**	**7,695**	**9,422**	**4.4**
Developing Asia	1,268	2,002	2,350	3,105	3,937	4,918	6,122	4.8
China	551	925	1,107	1,520	2,030	2,672	3,486	5.7
India	257	378	493	644	802	981	1,192	4.9
South Korea	95	181	190	237	285	335	387	3.2
Other Developing Asia	365	519	560	704	819	930	1056	3.0
Central and South America	449	604	735	950	1,162	1,421	1,728	4.5
Total World	**10,431**	**12,053**	**12,821**	**14,868**	**16,956**	**19,257**	**21,872**	**2.5**

Note: EE/FSU = Eastern Europe and the former Soviet Union.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

uncertainty. Its real GDP fell by 2.9 percent in 1998, according to WEFA Energy [1]. The Japanese government has, however, undertaken a $500 billion spending initiative aimed at reviving the economy. The Japanese central government's expansionary fiscal policies in the past have generally proven inadequate to the task of restoring economic growth, and little improvement is expected for Japan's economy in the near term.

In Russia, economic developments have grown more discouraging. Although difficulties in the Russian economy were heightened by events in Asia, the Russian government's persistent inability to undertake meaningful—and much needed—domestic economic reform continues to be the main roadblock to economic recovery. A moratorium on servicing government debt and the Russian government's recent plan to make good on payments on past-due salaries and pensions through printing money suggest that the Russian economy is likely to worsen further before getting better.

Downward pressure on financial markets and currencies in Central and South America was another fallout of the Asian economic crisis; however, not all of the region's current economic problems can be attributed to events in Asia. Brazil, for instance, has found itself in need of a $42 billion credit from the International Monetary Fund, largely because of its huge government budget deficit [2]. The credit was needed both to keep the Brazilian financial system solvent and to stem a run on the Brazilian currency.

For the developing nations of Africa and the Middle East, both economic growth and electricity consumption growth are expected to fall midway between those projected for the industrialized economies and the developing economies of Asia and Central and South America. Rising electricity demand in the Middle East will be linked more strongly with rapid population growth than with increases in per capita electricity usage. The outlook for Africa is similar, but the growth in electricity demand is expected to be slightly higher as access to electricity grids becomes more widespread. Both the Middle East and Africa depend strongly on extractive industries for economic growth. In both regions, economic growth and electricity consumption growth will be shaped by developments in the supplies of and demand for raw materials and petroleum.

Highlights of recent electricity developments around the world are as follows:

- The world's recent economic difficulties—which started in Asia but then moved to South America, Russia, and finally the western industrial economies—continue to restrain the near-term prospects for global economic growth. Again, in the near term, the electricity consumption growth forecast has been revised downward, particularly for Southeast Asian nations. Over the past year, several Southeast Asian nations have canceled or postponed a number of electricity projects. The effects of the crisis have been most immediately felt in Thailand, Indonesia, Malaysia, the Philippines, and South Korea, where project cancellations or delays have been most evident.

- Electricity pools have emerged in all corners of the globe: from Australia to Alberta; from South America to South Africa; from the United States to the

United Kingdom. Pools have in general improved the management of system capacity and reduced electricity prices; however, the possibility of short-term increases in price volatility has grown, with price spikes appearing during periods of heavy demand.

- Electricity trade accounts for a relatively small share of overall electricity supply. The strengthening of pool and system interconnections should increase such trade substantially over the forecast period. Such developments are underway in Central and South America, the Indian subcontinent, Europe, North America, parts of Asia, and Southern Africa.

- To date, in dollar terms, the privatization of electricity supply in the United Kingdom has been the largest transaction involving state-owned energy assets. Over the next year or two, Brazil will sell off a large part of its electricity industry, as well as its state-owned petroleum company. Once Brazil's electricity privatization plan is completed, one estimate expects the Brazilian national government and state governments to raise more than $60 billion from the asset sales [3]. Thus far, Brazil's privatization has also attracted billions of dollars in foreign investment, particularly from the United States.

- Some headway has been made toward the eventual ratification of the Kyoto accords. As of March 15, 1999, 83 countries, including the United States, had signed the Kyoto Protocol [4]. Adherence to the Kyoto Protocol's agreed-upon greenhouse gas reductions would alter both the forecast for future electricity fuel mixes and the electricity demand forecast itself; however, the *IEO99* projections do not reflect the possible ratification of the Protocol.

- Both South Korea and Thailand currently are undertaking greater market reform in their electricity sectors. In Thailand the electricity sector is being deregulated to allow independent and small power producers to sell electricity to Electricity Generating Authority of Thailand (EGAT). Thailand is also undertaking a partial privatization of EGAT. The Korean Electric Power Corporation, South Korea's state-run electricity monopoly, is slated to be privatized in 2002 [5].

Primary Fuel Use for Electricity Generation

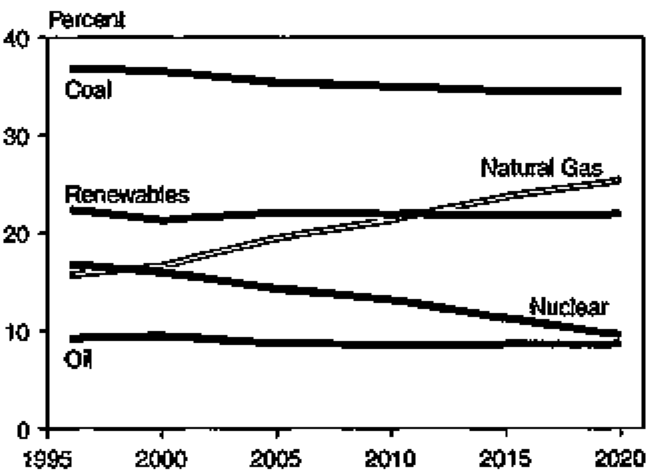
Natural Gas

Natural gas is increasingly becoming the fuel of choice for new electricity projects around the globe (Table 18). Over the 1996-2020 projection period, natural gas is expected to gain share in North American electricity generation markets relative to coal and nuclear power. South America is expected to increase natural gas consumption to supplement its large base of hydroelectricity generation. Western Europe is moving from nuclear to greater reliance on gas. Eastern Europe is expected to move from coal to gas. And a major share of capacity expansion in Asia and the Middle East will rely on natural gas.

Overall, natural gas is expected to account for 25 percent of world electricity fuels market in 2020, as compared with 16 percent in 1996 (Figure 65). Favoring natural gas are increased confidence in the availability of future supplies, significant improvements in gas turbine technology, the relatively smaller negative effects of gas-fired generation on air quality than those of other fossil fuels, and the increasing availability of imported liquefied natural gas (LNG). Although currently accounting for only 5 percent of world gas consumption, LNG exports have grown by 38 percent since 1992 [6]. Algeria, Indonesia, and Malaysia are the largest exporters of LNG, and Japan, South Korea, and France are the largest importers [7].

Pipeline trade in natural gas, currently almost triple the volume of LNG trade, is also growing rapidly. In recent years, exports of natural gas from Canada to the United States, from Norway and Russia to Western Europe, and from Algeria to Italy and Spain have led the increase. Upon the completion of a number of pipeline projects under construction or now being planned in South America, Argentina and Bolivia will become major exporters of natural gas and Chile and Brazil will become major importers.

Figure 65. Fuel Shares of World Electricity Generation, 1996-2020



Sources: 1996: Derived from Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

Table 18. World Energy Consumption for Electricity Generation by Region and Fuel, 1996-2020
(Quadrillion Btu)

Region and Fuel	1996	2000	2005	2010	2015	2020
Industrialized	**77.9**	**83.2**	**89.5**	**93.9**	**98.7**	**102.4**
Oil	5.2	5.8	5.3	5.2	5.5	5.7
Natural Gas	7.7	9.7	13.8	16.2	20.5	23.2
Coal	28.0	29.8	30.5	31.3	32.3	33.2
Nuclear	19.8	20.0	19.6	19.2	17.0	15.5
Renewables	17.2	17.8	20.3	21.9	23.3	24.8
EE/FSU	**24.4**	**23.8**	**26.1**	**27.4**	**28.9**	**30.8**
Oil	2.7	2.8	2.8	3.0	3.1	3.2
Natural Gas	9.6	9.7	11.3	12.7	14.2	16.1
Coal	6.4	5.9	5.9	5.3	4.4	3.9
Nuclear	2.8	2.8	2.9	3.0	3.1	2.7
Renewables	2.9	2.7	3.1	3.4	4.1	4.9
Developing	**41.1**	**46.4**	**58.2**	**69.8**	**81.4**	**93.8**
Oil	5.3	5.9	7.0	8.2	9.4	10.7
Natural Gas	5.2	6.3	8.8	11.8	14.8	18.3
Coal	18.5	20.3	25.1	30.3	35.5	41.2
Nuclear	1.5	1.7	2.4	3.0	3.5	3.6
Renewables	10.6	12.2	14.9	16.5	18.2	20.0
Total World	**143.4**	**153.4**	**173.8**	**191.1**	**209.0**	**227.0**
Oil	13.3	14.5	15.1	16.4	18.0	19.6
Natural Gas	22.5	25.6	33.9	40.8	49.6	57.7
Coal	52.8	56.0	61.5	66.9	72.2	78.3
Nuclear	24.1	24.5	24.9	25.2	23.6	21.7
Renewables	30.7	32.7	38.3	41.9	45.6	49.7

Note: EE/FSU = Eastern Europe and the former Soviet Union.

Sources: **1996:** Derived from Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

Nuclear Power

The nuclear share of the world electricity market is expected to drop sharply in the forecast, to 10 percent in 2020 from 17 percent in 1996. Nuclear power has lost its luster largely as a result of past cost overruns in building nuclear facilities, the high costs of decommissioning and spent fuel retirement, and growing environmental concerns. Both Sweden and Germany are committed to gradual phaseouts of nuclear power, and other industrialized nations are expected to reduce reliance on nuclear. In the United States, for instance, where nuclear power provided 20 percent of total electricity production in 1996, its share of the generation market is expected to fall to 8 percent by 2020. Only France and Japan are expected to continue to rely on nuclear power to the extent that they have in the past.

Coal

In the future, as in the past, coal is expected to dominate electricity fuel markets, although its share is projected to decline slightly, to about 35 percent in 2020 from 37 percent in 1996. China is expected to have the highest growth in electricity-related coal demand at more than 4 percent annually. In 2020, China is projected to account for nearly one-third of the world's coal consumption for electricity generation, up from 17 percent in 1996. China has been the leading consumer of coal since 1982, followed by the United States. India's coal consumption is also expected to grow strongly, along with its consumption of natural gas. In the United States, coal use in the electricity sector is projected to increase by about 1 percent per year between 1996 and 2020.

For the nations of Western Europe, coal consumption is expected to decline. Western European countries are relying on increasingly available natural gas supplies for future growth in electricity production. The elimination of subsidies in the United Kingdom was largely responsible for a 50-percent drop in the nation's coal production between 1989 and 1997 and a greatly reduced role for coal in electricity generation. In recent years both coal production and consumption have also dropped off sharply in Eastern Europe and the former Soviet Union

(EE/FSU), and further declines in coal consumption by electric utilities in the EE/FSU region are expected. In large measure, coal's lost share of the EE/FSU electricity market will be taken over by natural gas.

Hydroelectric and Other Renewables

The use of renewable energy sources (primarily hydropower) for electricity generation is expected to remain stable over the forecast period, accounting for 22 percent of total electricity supply in 2020, compared with 21 percent in 1996. For the world to maintain its present degree of reliance on hydroelectric power will require substantial capacity expansion, most of which is expected to occur in China and other Asian nations.

Currently, no other region is as dependent on hydroelectric power as is South America. Although the region accounts for only 5 percent of the world's total electricity generation, it accounts for 18 percent of the generation from hydropower. South America is expected to increase its output of renewable-based electricity from 5.4 quadrillion Btu in 1996 to 7.7 quadrillion Btu in 2020, but increasing use of natural gas is also expected to reduce the region's reliance on hydropower for electricity generation.

Among the developing countries of Asia, China and India account for more than two-thirds of renewable-based electricity generation. China's growth in renewables will be strongly influenced by additional capacity associated with the gradual completion of the 18.2-gigawatt Three Gorges Dam and other large hydropower projects. The Three Gorges Dam project is scheduled to be fully operational by 2009. Although India currently produces far less hydroelectricity than China, renewables still accounted for 13 percent of India's electricity generation capacity in 1996 and are expected to account for more than 18 percent of its capacity in 2020.

Regional Highlights

Asia

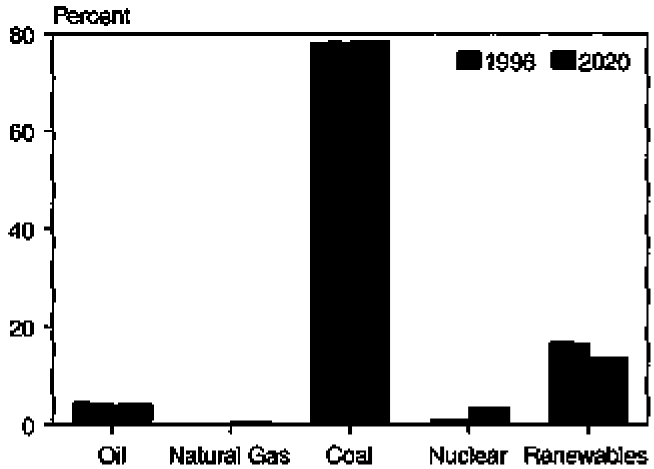
China

Overall, China is expected to add more to its electricity generation capacity than any other nation—more than twice the projected new capacity additions in the United States between 1996 and 2020. China is far and away the largest economy in developing Asia, accounting for roughly one-third of the region's economic activity. China has also had the region's fastest rate of economic growth in recent years. Although its growth has slowed, the Chinese economy appears to have weathered the worst effects of the Asian financial crisis.

China's current 250,000 megawatts of installed electricity generation capacity is second only to that of the United States [12]. Electricity consumption in China is expected to grow at a 5.7-percent annualized rate over the 1996-2020 period. Despite substantial recent growth in electricity supply, per capita consumption of electricity is currently one-sixteenth of that in the United States, and 10 percent of China's population has no access to the grid. Thus, future development will entail substantial additional investment in power supply.

China has the world's second largest coal reserves and is both the world's largest producer and consumer of coal. For the most part, however, the reserves lie in the interior region of the country, far away from coastal economic activity. China currently is promoting the building of minemouth electricity plants rather than constructing additional rail lines to transport coal to eastern regions [13]. China's reliance on coal for electricity generation is expected to remain stable at roughly three-fourths of the total (Figure 66).

Figure 66. Fuel Shares of Electricity Generation in China, 1996 and 2020



Sources: **1996:** Derived from Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **2020:** EIA, World Energy Projection System (1999).

After coal, renewables account for the second largest share of China's electricity generation market, having a 17-percent overall share in 1996. From 1996 to 2010 hydroelectric capacity is expected to double and its share of China's total electricity generation is expected to increase, largely as a result of completion of the Three Gorges Dam and other large-scale hydropower projects. By the time it becomes fully operational in 2009, Three Gorges Dam will have an installed capacity of 18.2 gigawatts. After 2010, growth in renewable energy is expected to moderate, and its share of the electricity market is expected to fall.

Although nuclear power currently accounts for only a small share of China's electricity generation (under 1 percent in 1996), its share is expected to be nearly 4 percent by 2020. The United States has recently removed export barriers to Chinese purchases of reactors from U.S. manufacturers [14, p. 62]. Companies from France, Japan, the United States, and the United Kingdom currently are planning or carrying out nuclear power construction projects in China.

Foreign investment has played a critical role in financing the expansion of China's electric power infrastructure and is expected to be even more important in the future. Between 1979 and 1996, foreign investment accounted for 10 percent of China's total investment in electricity generation: approximately $13 billion in foreign funds helped finance the construction of 87 Chinese power plants with a capacity of 58,000 megawatts [15]. For the 1996-2000 period, China expects foreign investment to supply 20 percent of its electric power investment capital [15]. To increase their access to overseas capital, several of China's electricity companies have recently acquired listings on the New York Stock Exchange and stock exchanges in London and Hong Kong.

During the late 1980s China implemented electricity reforms aimed at reducing government's managerial role in electricity supply [16]. In 1987 the government allowed for a "fuel cost rider" enabling generation companies to pass on higher fuel input costs to consumers. In 1998, electricity prices for rural areas were deregulated. These and other reforms were aimed at increasing the attractiveness of investments in China's electricity sector. For example, in awarding a contract for the financing of the 700-megawatt coal-fired Laiban B power project, rather than negotiating an allowable rate of return, China's government chose to auction off the project to the bidders offering the lowest price per kilowatt of capacity. Before the Laiban B deal, foreign investors had often criticized China's allowable rates of return on electricity investment as being too low [17].

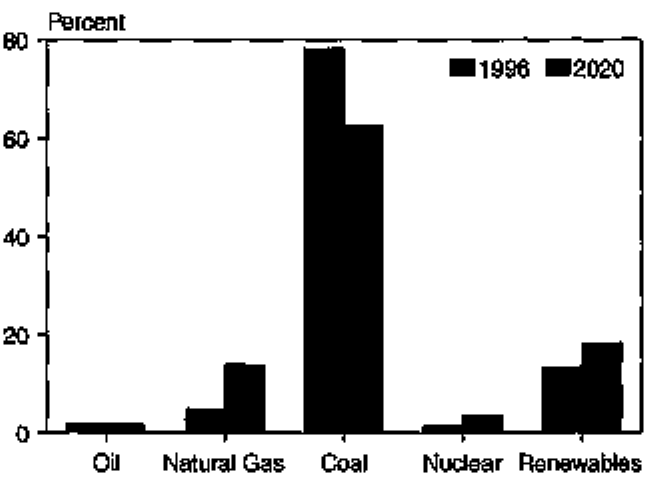
India

Second only to China among developing countries in terms of population and economic activity, India is expected to increase its consumption of electricity at a 4.9-percent average annual rate from 1996 through 2020. India's heavy reliance on coal for electricity generation is expected to lessen somewhat over the next 25 years. By 2020, coal's share of the market is expected to decline to 62 percent from 79 percent in 1996 (Figure 67). Natural gas will largely make up for coal's lost share, accounting for 14 percent of the electricity fuels market in 2020, compared with 5 percent in 1996. India's use of nuclear and hydropower for electricity generation is also projected to increase in the forecast.

As in China, foreign investment is key to the financing of India's power sector expansion. The Indian government opened up the power sector to private investment in 1991 with the passage of an amendment to the 1948 Electricity Supply Act allowing for the construction of independent power projects. In December 1996, the Indian central government announced a new policy for electricity development [18]. Called the "Common Minimum National Plan for Power," the policy intends to restructure and corporatize the state electricity boards, to allow them greater autonomy, and to allow them to operate along commercial lines. The plan also attempts to facilitate the approval process for private power projects selected for competitive bidding by the central government. In June 1998, the central government further eased its rules on foreign investment in the power sector. Automatic approval is to be given to projects in excess of 15 billion rubees (about $355 million) involving 100 percent foreign equity.

The removal of subsidies flowing from urban electricity consumers to rural users has been a serious issue as India has undertaken electricity reform. The subsidies have been substantial, and in some regions their removal would lead to sizable increases in rural electricity rates. The Indian government's Electricity Regulatory Commission issued an ordinance in 1998 directed at rationalizing electricity tariffs and subsidy policies. Under the order, the state regulatory entities would have the authority to remove rural subsidies [19].

Figure 67. Fuel Shares of Electricity Generation in India, 1996 and 2020



Sources: 1996: Derived from Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). 2020: EIA, World Energy Projection System (1999).

Other Developing Asia

Other developing Asian nations are also expected to have rapid growth in electricity consumption over the coming years. Although in the near term many other Asian economies have slipped into recession—some for the first time in recent memory—their previous economic growth rates are expected to be reestablished over the next few years. Electricity consumption for the collective region is expected to grow at a 3-percent average annual rate between 1996 and 2020.

Coal plays a much smaller role in the electricity industries of other developing nations of Asia than it does in China and India. In 1996, the region as a whole depended on coal for 31 percent of generation, renewables for 21 percent, and oil for 20 percent. No other world region outside the Middle East currently depends so heavily on oil as a source of electricity generation. By 2020, however, oil is projected to account for only 16 percent of the electricity fuels market in the other developing Asia region. Renewables will also decline in importance, with a projected 16-percent share in 2020.

For the most part, natural gas is expected to supplant oil and renewables in the region's electricity generation mix, increasing from 21 percent of the electricity fuels market in 1996 to 33 percent in 2020. In the near term, the most rapid growth will be in the use of imported LNG.

Foreign investors have played a role in funding many ongoing power projects in developing Asia; however, the Asian economic crisis has had a variety of negative effects on a number of projects. First, the reduced rate of economic growth has slowed electricity consumption, undermining the need for capacity expansion. Second, the crisis has also produced a sharp drop in currency values, effectively raising the costs of imported fuels. Third, many of the foreign investments are to be paid back in foreign currencies against which many of the region's currencies have been depreciated. In total, an estimated 11 gigawatts of new capacity has been postponed or canceled [20]. Further, with the severe drop in the value of regional currencies, electricity prices have been raised extensively in order to meet financing obligations.

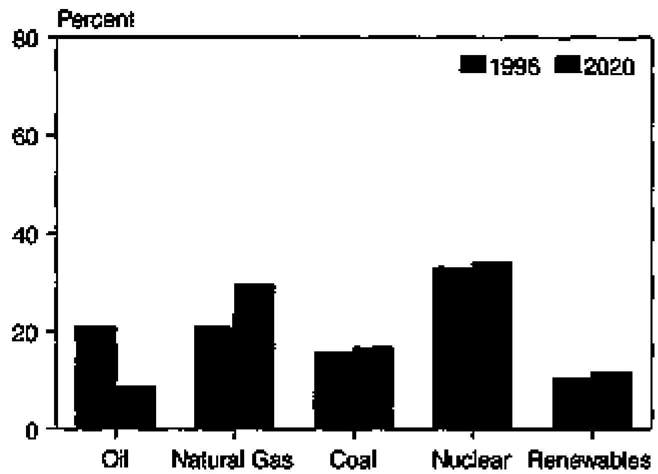
Nowhere has the crisis been more pronounced than in Indonesia. In addition to slowing the near-term projected growth of electricity demand, the crisis has brought about a major devaluation of the nation's currency, the rupiah. Many of the power contracts signed by the state-owned power company, Perusahaan Listrik Negara (PLN), with independent power producers were completed when the Indonesian currency was at its pre-crisis exchange value of around 2,300 rupiahs to the dollar. Currently, a dollar trades for 7,500 rupiahs, making many contracts unsustainable. The PLN has been trying both to renegotiate the contracts and to raise domestic electricity prices.

Thailand has had more success in the renegotiation of its electricity contracts with private developers, and most private power agreements have been successfully renegotiated. In Malaysia, however, the 2,400-megawatt Bakun hydroelectric power project has been temporarily tabled until the central government agrees to sponsor the project, and the 1,500-megawatt Penang project remains delayed [20]. The Bakun hydroelectric power project was scheduled to be completed in 2002.

Japan

Japan's annual growth in electricity consumption is expected to average 1 to 2 percent over the projection period, reflecting the nation's advanced level of economic development and slow population growth. Currently, Japan produces one-third of its electricity with nuclear power, second only to France among the nations of the Organization for Economic Cooperation and Development (OECD). Japan is expected to continue construction of nuclear power plants, slightly increasing its reliance on nuclear power from 33 percent of its total electricity needs in 1996 to 34 percent in 2020 (Figure 68). On the other hand, growing public opposition to nuclear power could intensify in future years and, perhaps, reverse the nation's commitment to the nuclear power option. Japan's dependence on natural gas for electricity generation is also expected to grow slightly in the forecast, mostly in the form of LNG. Japan is by far the world's largest importer of LNG, most of which comes from Indonesia and Malaysia.

Figure 68. Fuel Shares of Electricity Generation in Japan, 1996 and 2020



Sources: 1996: Derived from Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). 2020: EIA, World Energy Projection System (1999).

Electricity prices in Japan are among the highest in the world. As a result, in April 1995, Japan amended its Electricity Business Act. The goals Japan sought to achieve via the amendment included forcing open access in generation and allowing nontraditional suppliers to engage in direct sales. Before the amendment, any sales by nontraditional suppliers required approval from one of Japan's 10 traditional generation companies. The amendment also allowed for tariff reform, giving electricity suppliers more discretion over setting prices. Wholesale wheeling was also introduced. The amendment also included a regulatory reform initiative, adopting a performance-based model of price regulation that first appeared in the United Kingdom after its utility reform. Japan's reforms were furthered in 1998, when the Ministry of Trade and Industry allowed industrial companies (i.e., nonutilities) to sell electricity directly to large consumers.

In the near term, Japan's inability to extricate itself from its current economic difficulties has cast some doubt on the future of the Japanese economy and when it will return to its earlier growth trend. In the fall of 1998, the Japanese parliament passed a $500 billion reform package that is intended to recapitalize the Japanese banking industry. To date, there have been few signs of economic recovery in Japan.

Central and South America

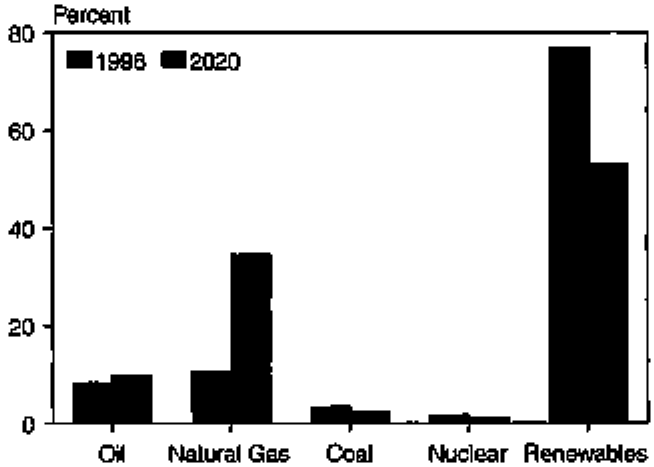
For the forecast period, after developing Asia, Central and South America is projected to realize the fastest growth in electricity consumption. In the very near term, however, Central and South America is expected to be the most dynamic of all developing regions in terms of electricity consumption growth. In the *IEO99* reference case, the region's electricity use is expected to average 4.5-percent growth per year between 1996 and 2020. Brazil, which accounts for about half the region's economic activity and population, is expected to see electricity consumption growth of nearly 5 percent annually.

Currently, roughly 30 percent of the population in Central and South America has no access to the grid, and per capita electricity consumption for the region is roughly 12 percent of that in the United States. By 2020, however, per capita electricity consumption in Central and South America is expected to nearly double.

Central and South America is projected to rely increasingly on natural gas as a fuel for electricity generation (Figure 69), with the gas share of the electricity market growing from 10 percent in 1996 to 34 percent in 2020. Currently, oil, coal, and nuclear together account for 14 percent of the region's electricity generation. That share is expected to remain relatively stable over the forecast period.

The growth in natural gas use for electricity generation will depend on the completion of several major pipeline projects linking producing countries, such as Argentina and Bolivia, with consuming countries, such as Chile and Brazil. Once those projects are completed, a regional natural gas pipeline will be in operation in South America. In addition, a continent-wide market for electricity is also evolving in South America. Currently, Argentina, Brazil, Venezuela, Chile, and Ecuador are completing a unified electricity transmission system. The grid is being established in part to help diminish hydroelectricity shortages during droughts, which have been fairly serious in recent years [21].

Figure 69. Fuel Shares of Electricity Generation in Central and South America, 1996 and 2020



Sources: **1996:** Derived from Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **2020:** EIA, World Energy Projection System (1999).

Uruguay, in an attempt to establish itself as a hub of regional electricity trade, is promoting a number of transmission and generation projects that would connect Argentina with Brazil through Uruguay [22]. In 1997, the governments of Argentina and Brazil signed a letter of understanding that allows for less government interference in electricity trade between the two countries [23]. Foreign companies are playing a growing role in providing electricity to the continent. Enron won the bid to construct an interconnection between Argentina and Brazil that will allow for the export of 1,000 megawatts of power from Argentina to Brazil. In 1997, National Grid of the United Kingdom announced plans to build a transmission line between the Argentine coast and the Andes at a cost of $250 million. Venezuela also intends to sell surplus electricity to Brazil [24], and Venezuela's Edelca has proposed the construction of a 2,600-mile line linking the two countries [25].

The InterAndes electricity transmission line, when completed, will allow exports of electricity from Argentina to Santiago, Chile. The transmission line, being financed by Chilgener, Chile's second largest electricity generator, will run 700 miles at a cost of $575 million. Chilgener will also build two 350-megawatt combined-cycle gas plants in Salta, Argentina, to provide the power. Santiago suffers from serious air pollution resulting in part from oil- and coal-fired electricity generation.

There is also a regional electricity grid evolving in Central America, although at a hesitant pace. In December

1995, the presidents of Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama endorsed a proposal to construct a $350 million, 930-mile high-voltage transmission line (SIEPAC) connecting Guatemala, Honduras, and Panama [26]. The transmission line is being financed by the Inter-American Development Bank, the government of Spain, and a Spanish utility. Although the grid is scheduled to be completed in 2003 or 2004, the parties involved have proceeded cautiously thus far in light of criticism from the World Bank [26].

Brazil is currently in the process of privatizing and deregulating its electricity industry. Privatization of electricity in Brazil has been taking place in the context of a concerted effort at overall economic reform. Privatization-related sales of the nation's electricity assets will be among the world's largest energy-related financial transactions in 1997, 1998, and 1999. By late 1997, roughly $60 billion in Brazilian electricity assets had been slated for privatization [3]. The privatizations have attracted billions of dollars in foreign investment, most of which came from U.S. companies.

Western Europe

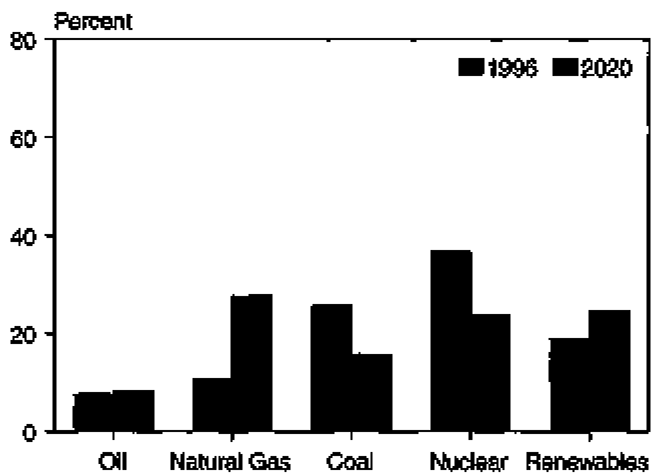
Western Europe is projected to average roughly 2-percent annual growth in electricity consumption from 1996 to 2020—higher than the rate for the United States, Canada, or Japan—based in part on the expectation that current measures aimed at unifying the region both financially and economically will improve its long-term prospects for growth. Most of the increase is expected to be met by gas-fired generation. For more than two decades, Western Europe has been reducing its reliance on coal and oil as electricity generation fuels. They accounted for 40 percent and 22 percent of the region's generation market, respectively, in 1970 but only 26 percent and 8 percent in 1996. By 2020, coal's share of the market is expected to slip to 16 percent, and oil's share is expected to remain at 8 percent (Figure 70).

Only France is expected to retain a high degree of reliance on nuclear power, at 71 percent of electricity consumption in 2020 (compared with 80 percent in 1996). Other West European nations are expected to reduce their reliance on nuclear power [14, p. 56]. Germany, for instance, has announced plans for a complete phaseout of nuclear power, which currently supplies about 32 percent of its electricity generation. In the United Kingdom, reliance on nuclear power is expected to fall from 34 percent of the power market in 1996 to 19 percent in 2020. Sweden has long planned to phase out nuclear power but has delayed implementation several times.

Europe currently is undergoing a transition to a continent-wide wholesale market in electricity. A 1996 directive by the European Community requires all signatories to open their domestic electricity markets to new suppliers starting in February 1999.[16] In the initial implementation period (during 1999), 25 percent of each participating nation's electricity market is to be opened to competition. In 2006, signatory countries will be required to open up one-third of their electricity markets to new suppliers. Although the definition of competitive access is still being debated, the anticipated onset of competition has led to some transnational acquisitions by European electricity companies eager to engage in cross-border trade.

Western Europe has also seen some moves toward the introduction of consumer choice in the retail electricity market. The Nordic nations implemented fully competitive supply markets at the retail level in 1996, and today households in Finland, Norway, and Sweden are allowed to choose their electricity suppliers. The recently privatized electricity industry in the United Kingdom moved one step closer to full competition in 1998. In September, London residents became eligible to nominate their preferred electricity suppliers. In June 1999, virtually all households in England and Wales are scheduled to have the option of choosing a preferred electricity supplier.

Figure 70. Fuel Shares of Electricity Generation in Western Europe, 1996 and 2020



Sources: **1996:** Derived from Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **2020:** EIA, World Energy Projection System (1999).

Eastern Europe and the Former Soviet Union

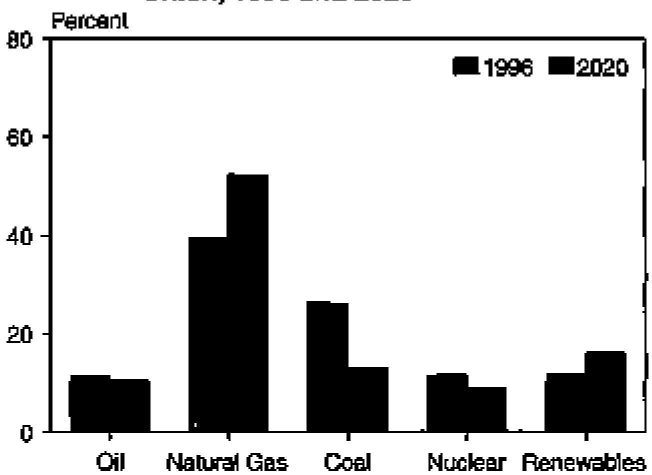
In November 1998, the Russian government announced that it would be unable to pay the interest on debts to its international creditors for 1998 and 1999. Economic growth, which began to head in a positive direction in 1997 for the first time in 7 years, turned negative again in 1998. Several years of political instability, compounded

[16]Greece and Ireland were allowed to delay compliance with the directive for 2 years.

most recently by financial insolvency, raise severe doubt about the prospects for recovery. However, most of the Eastern European nations maintained positive economic growth rates in 1997, and their projected growth rates in *IEO99* are changed little from last year.

The FSU and much of Eastern Europe suffer from an antiquated electricity supply infrastructure. Future investment will be directed in large part to upgrading the industry to the standards of industrialized nations. Coal accounted for 26 percent of electricity generation in Eastern Europe and the FSU in 1996. By 2020, in contrast, coal's share is expected to fall to 12 percent, largely being replaced by hydropower and Russian natural gas (Figure 71). Reliance on nuclear power in Eastern Europe is also expected to fall steadily over the forecast period.

Figure 71. Fuel Shares of Electricity Generation in Eastern Europe and the Former Soviet Union, 1996 and 2020



Sources: 1996: Derived from Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). 2020: EIA, World Energy Projection System (1999).

North America

United States

Electricity consumption in the United States is projected to increase at an average rate of 1.2 percent per year from 1996 to 2020—one of the smallest increases expected among the industrial economies. Demand growth in the United States has slowed considerably since the 1960s, when electricity consumption was rising at a rate of 7 percent per year. Saturation of households with electronic appliances and efficiency improvements in such appliances over time are responsible for the slower growth in total electricity consumption [27].

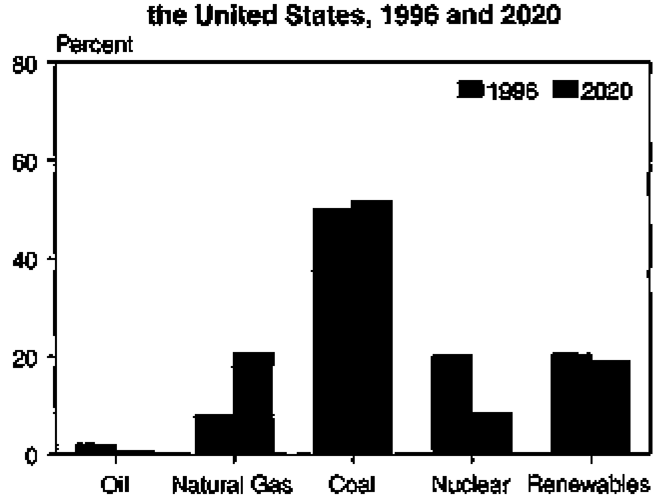
The United States is expected to significantly reduce its reliance on nuclear power as a source of electricity generation over the forecast period. Nuclear power, which accounted for 20 percent of total U.S. electricity generation in 1996, is expected to drop to 8 percent by 2020. Coal's share of the U.S. electricity fuels market is expected to hold steady at roughly 50 percent (Figure 72), and the 20-percent share of renewables in 1996 is also expected to remain stable. Natural gas and, to a much smaller extent, coal will largely supplant nuclear power in the United States. No new nuclear power plants have come on line in the United States since 1996, and none is expected in the future. Deregulation, as it forces decisionmakers to address the issue of stranded costs, could hasten the move away from nuclear power.

In 1998, California opened its market to the retail sale of electricity and became the first State to allow consumer choice of electricity providers at the household level. Early indications are, however, that the availability of consumer choice did not induce many household users to switch from their incumbent suppliers. Enron, which entered the California retail market more aggressively than any other company, pulled out just 3 weeks after it entered.

In 1998, California also started the California Power Exchange, establishing a deregulated market for electricity in the State for the first time. The Power Exchange is open to all buyers and sellers of electricity and provides a vehicle to bring electricity supply and demand together. An Independent System Operator was also established with the mandate of focusing on reliability.

The electricity industry and the financial industry have also become more interlinked in the United States and will continue to do so in the future. In 1996, trading in electricity futures started on the New York Mercantile Exchange. Further, in recent years, several utilities have set up trading operations and some have established relationships with financial institutions to better

Figure 72. Fuel Shares of Electricity Generation in the United States, 1996 and 2020



Sources: 1996: Derived from Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). 2020: EIA, World Energy Projection System (1999).

manage risk exposure in an era of growing volatility in electricity prices.

Regional wholesale markets have also emerged. The introduction of wholesale trading of electricity has seen some difficulties, however. In July 1998, a weather-related consumption spike in the Midwest was coupled with some unexpected loss of generation capacity. Together the developments led to nondelivery of some contracted electricity supplies and a 1-day runup of electricity prices to as high as $5,000 per megawatthour. Similar price spikes have occurred in the United Kingdom, Australia, and Alberta, Canada with the introduction of wholesale electricity markets.

Canada

Canada is also expected to see relatively slow growth in electricity consumption over the forecast period. Between 1996 and 2020, annual growth in Canadian electricity consumption is projected to average 1.4 percent.

Like the United States, Canada is expected to reduce its dependence on nuclear power over the coming years. Nuclear power, which accounted for 17 percent of Canada's total electricity generation in 1996, is expected to provide only 7 percent of total supply in 2020. In all likelihood, Canada may reduce its dependence on nuclear power even more dramatically. Currently, Ontario is reevaluating the safety of its nuclear power industry. In late 1997 and early 1998, Ontario Hydro shut down seven of its older power plants, or 17 percent (4,300 megawatts) of its operating capacity. At present, it remains uncertain whether the plants will be brought back on line sometime after 2000 as was intended. Historically, the United States has been a net importer of electricity, primarily from Canada. If the plants are not reopened, the net flow of electricity across the U.S.-Canadian border could be reversed. Natural gas will in large measure make up for Canada's reduced reliance on nuclear power and hydroelectricity.

Also like the United States, Canada is currently attempting to reform its electricity sector. Most reform efforts are taking place at the provincial level and are motivated by a desire to reduce electricity costs. The reforms should serve to integrate the U.S. and Canadian electricity markets more closely and increase electricity trade.

Provincial governments in Canada are largely responsible for electricity policy. In recent years the provincial government of Alberta has been a leader in electricity reform. Alberta's Electric Utility Act of 1995 created a competitive market in generation, instituted location-based rates, and set up a power pool for spot trading in electricity [28].

In April 1997, Hydro Québec petitioned the U.S. Federal Energy Regulatory Commission (FERC) for permission to sell electricity in the United States in return for allowing U.S. competitors to wheel electricity into Québec. FERC Order 888 compels U.S. utilities to open their transmission lines to all newcomers, although they can refuse access to any supplier who fails to provide reciprocal treatment. Until deregulation, Canadian utilities were allowed to sell power only into U.S. transmission grids immediately adjacent to their provincial borders. Eastern New York State and parts of New England obtained some power from Hydro Québec, and Ontario Hydro sold into western New York. In November 1997, Hydro Québec received FERC approval to sell power in the United States at market-based rates. FERC attached no conditions to its decision, indicating that it was satisfied that Hydro Québec had met the agency's reciprocity requirement and had adequately opened its market to competitors. Hydro Québec made a major concession to the FERC by agreeing to allow outsiders to transmit electric power over its grid to nine municipal wholesalers and one municipal cooperative, beginning in May 1997.

Mexico

Mexico is expected to lead North America in electricity consumption growth, largely because of its higher projected rate of economic growth and its lower starting base in terms of per capita electricity consumption. Over the 1996-2020 period, Mexico's electricity consumption is projected to grow at a rate of nearly 4 percent per year.

Plagued by serious air pollution, Mexico has been aggressively moving away from oil-fired generation to natural gas. In order to finance future electricity infrastructure to meet the needs of a rapidly growing population and economy, the Mexican government is actively encouraging the development of private power projects. Mexico currently allows private investment in independent power production, although all sales from such operations must be directly to the state-owned utility, Comision Federal de Electricidad (CFE). Several U.S. companies have undertaken investments in gas-fired generation facilities in Mexico. In February 1998, President Zedillo proposed to the Mexican congress that private companies should be allowed to invest in the leasing and construction of power plants and regional transmission lines. The proposal would allow large consumers of electricity to bypass the CFE and buy directly from generators [29].

Africa and the Middle East

Africa

South Africa accounts for 61 percent of all the electricity generated on the African continent and, in combination with Egypt, Algeria, Libya, and Morocco, 89 percent of the continent's total electricity production. The continent as a whole is expected to see electricity consumption grow at a 3-percent annual rate from 1996 to 2020.

Several African countries have recently opened up their electricity sectors to private investment. Privatization efforts have been led by Morocco. In 1997, CMS Energy and the Swedish/Swiss company, Asea Brown Boveri, began construction on the Jorf Lasfar power plant. The $1.5 billion coal-fired plant will have a capacity of 1,360 megawatts upon completion in 2000 [30]. The plant, which is the largest of its kind to date in Africa, will eventually provide Morocco with about 30 percent of its electricity supply.

In 1996, the Egyptian cabinet approved the startup of a build-operate-transfer (BOT) program involving 1,600 megawatts of power [31]. The Ivory Coast is also using a BOT arrangement to finance, build, and manage major infrastructure projects without increasing its debt level. Twelve projects have been proposed thus far, and five have been awarded to private operators, including a new thermal electric generation facility near Abidjan [32]. Nigeria too is attempting to encourage foreign participation in electricity generation. In late 1998, Mobil announced that it had contracted to build a 350-megawatt natural-gas-fired independent power project in Nigeria [33].

Middle East

Almost two-thirds of the economic output of the Middle East region is accounted for by Iran and Saudi Arabia, along with half the region's electricity consumption. Iran is the most populous country in the Middle East, and Saudi Arabia has one of the highest per capita incomes. Other large users of electricity in the Middle East include Israel, Iraq, and Kuwait. Largely as a result of growth in the region's dominant economies, electricity consumption in the Middle East is expected to grow at a 3-percent annual rate over the projection period. Among Middle Eastern nations, Israel took a step towards privatization recently. In 1996, Israel's parliament passed a new electricity law allowing the Energy Minister to grant permits to independent power producers [31].

The Middle East depends heavily on petroleum to fuel its electricity generation. Oil-fired generation accounted for 38 percent of all electricity produced in 1996 and natural gas 36 percent—levels that are expected to continue throughout the forecast. Over the next few years, Iran is expected to complete its first nuclear power plant, and by 2020 nuclear power is expected to account for 2 percent of the region's electricity production.

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Transportation Energy Use

Transportation energy use is projected to constitute more than half of the world's oil consumption in 2020. Developing nations account for more than half the expected growth in transportation energy use in the IEO99 forecast.

The *International Energy Outlook 1999* (*IEO99*) presents a more detailed analysis than in previous years of the underlying factors conditioning long-term growth prospects for worldwide transportation energy demand. A nation's transportation system is generally an excellent indicator of its level of economic development. In many countries, personal travel still means walking or bicycling, and freight movement often involves domesticated animals. High rates of growth from current levels in developing countries such as China and India still leave their populations with very limited transportation services in 2020 by industrialized standards.

Currently, transportation energy accounts for 48 percent of world oil demand (Table 19). Since 1970 transportation energy demand has grown by 110 percent or 18 million barrels of oil per day. The *IEO99* reference case projection indicates growth in transportation fuel use of 77 percent or 27 million barrels per day by 2020. Virtually all demand growth involves increased use of oil products, and transportation accounts for 69 percent of the projected growth in oil demand over the next two decades. On a percentage basis, the increase in transportation energy consumption more than doubles the projected rise in world population. Developing countries account for 55 percent of the expected growth in transportation energy demand.

Growth in transportation sector energy demand within the industrialized countries, where modern transportation systems have been in place for many decades, is expected to average only 1.6 percent per year; but even in the most economically advanced countries, transportation energy use per capita continues to increase as people opt to drive larger and larger cars and as higher per capita incomes allow people to travel increasingly by air for long-distance vacations (Figure 73). Aggregate demand for transportation fuels in the industrialized countries in 2020 is projected to be about 10 million barrels per day higher than it was in 1996, reaching 34 million barrels per day (Figure 74). In many countries of the industrialized world, road congestion and vehicle ownership saturation may ultimately limit expansion of transportation sector energy demand [1, pp. 181, 210]. Car ownership in the United States and Canada is the highest in the world, and in these countries it is expected to reach saturation by the end of the projection period.

Energy use for transportation has increased sharply in industrialized Asia in recent years, in part as the result of a shift to larger cars in Japan [1, p. 234], where the share of passenger cars with an engine capacity of more than 119 cubic inches increased from about 4 percent in 1989 to more than 21 percent in 1996. Although the Japanese economy has expanded more slowly in this decade than

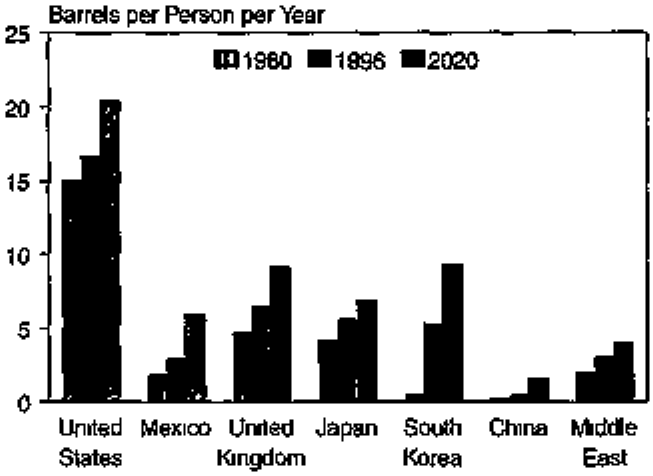
Table 19. World Oil Consumption Trends, 1980-2020

Year	Developing Countries		Industrialized Countries		World Total	
	Transportation	Total	Transportation	Total	Transportation	Total
Oil Consumption (Million Barrels per Day)						
1980	4.5	12.2	16.5	39.9	23.5	63.1
1990	6.8	17.0	20.9	39.0	31.0	66.0
1996	9.6	23.1	23.3	42.7	34.6	71.5
2010	17.0	37.0	29.9	50.1	49.9	93.5
2020	24.2	48.7	33.7	54.5	61.3	110.1
Annual Growth in Oil Consumption (Percent per Year)						
1980-1996 . . .	5.1	4.1	1.7	0.4	2.1	0.8
1996-2020 . . .	3.9	3.2	1.6	1.0	2.4	1.8

Note: World totals include Eastern Europe and the former Soviet Union (EE/FSU).

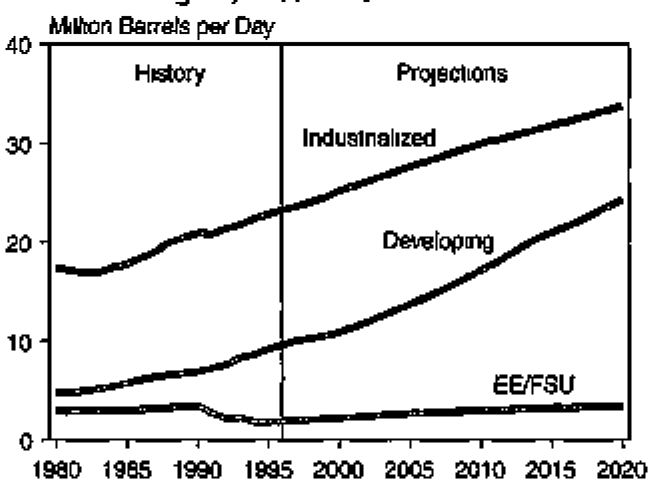
Sources: **1980-1996:** Derived from Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **1996-2020:** EIA, World Energy Projection System (1999).

Figure 73. Transportation Energy Use per Capita by Country, 1980, 1996, and 2020



Sources: 1980: Derived from Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database. 1996: Derived from EIA, *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). 2020: EIA, World Energy Projection System (1999).

Figure 74. Total Transportation Energy Use by Region, 1980-2020

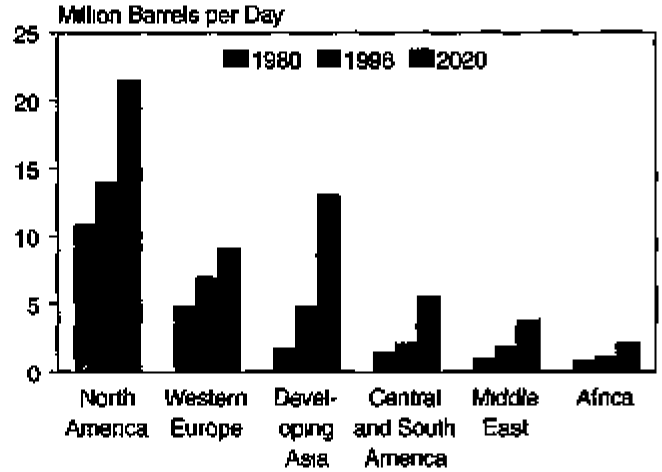


Sources: **History:** Derived from Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

in the last, energy demand in Japan's transportation sector has increased more rapidly in the 1990s than it did in the 1980s.

Projected long-term economic growth in the developing regions of the world is the key force for expanded transportation energy use over the projection period. In the developing countries, transportation energy use is projected to grow at an average annual rate of 3.9 percent between 1996 and 2020, more than double the rate of growth in the industrialized countries (Figure 75). Expected incremental annual consumption totals almost 15 million barrels per day—an amount greater than North America's total demand for transportation energy in 1996. The greatest gains are expected in developing Asia and Central and South America,[17] where transportation energy demand has tended to keep pace with high rates of economic growth.

Figure 75. Total Transportation Energy Use by Region, 1980, 1996, and 2020



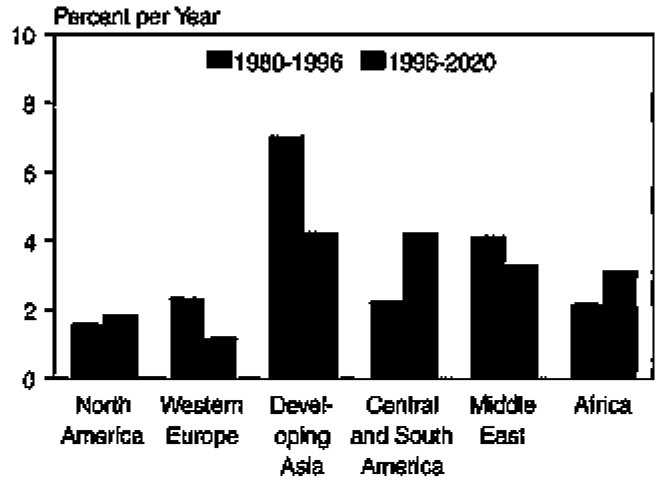
Sources: 1980: Derived from Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database. 1996: Derived from EIA, *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). 2020: EIA, World Energy Projection System (1999).

The transportation sector underwent fast-paced growth in developing Asia in the 1990s. In fact, several countries in this region, including South Korea, Malaysia, and Thailand, had growth rates of more than 10 percent per year in the first part of the decade [2, p. 10]. Although the economic recession that began in 1997 and continued through 1998 has dampened the short-term expectations for growth in transportation energy use, the *IEO99* reference case still projects growth of 4.2 percent annually between 1996 and 2020 in developing Asia (Figure 76). In China alone, transportation sector energy consumption is expected to grow by almost 7 percent per year as the government pledges major investments in the country's transportation infrastructure, including railway, road, and inland waterways. In 1997, Chinese Premier Li Peng announced that China would add some 3,400 miles of railroad and 68,000 miles of road between 1995 and 2000 [2, p. 59].

In Central and South America, energy use in the transportation sector is also expected to grow by 4.2 percent

[17]Central and South America comprises two regions modeled in the World Energy Projection System—Brazil and the rest of Central and South America. Mexico—included in North American totals in this report unless otherwise noted—is also projected to sustain high rates of growth. Individual forecasts for Mexico are provided in Appendix E.

Figure 76. Growth in Total Transportation Energy Use by Region, 1980-1996 and 1996-2020



Sources: 1980-1996: Derived from Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). 1996-2020: EIA, World Energy Projection System (1999).

annually over the projection period. Argentina and Brazil have the most advanced transportation infrastructures in the region, with motor vehicle densities of 170 and 93 per thousand population, respectively, in 1995 (compared with 30 vehicles per thousand people in Peru) [3, p. 11]. In Argentina, rising per capita income over the past several years has meant a rapid increase in demand for automobiles. Automobile and truck production increased by 42 percent in 1997 to meet Argentina's vehicle needs, as well as those of other Mercosur trading nations[18] [4, p. 32].

The EE/FSU region shows some growth in transportation energy use in the forecast, but the projected gains barely counter the effects of the recent disastrous economic decline in the region. Energy consumed in the transportation sector in the EE/FSU region is about 45 percent lower than it was in 1990. Most of the decline is attributed to countries in the former Soviet Union, where transportation sector energy use fell from 2.7 million barrels per day in 1990 to a low of 1.2 million barrels per day in 1994. Since then, energy use for transportation has stabilized and increased slightly to 1.3 million barrels per day in 1996; but in the *IEO99* reference case, energy demand in the FSU transportation sector does not recover to its 1990 level by the end of the projection period. In contrast, transportation energy use in the countries of Eastern Europe, which are well on the way to economic recovery, has already nearly returned to its 1990 level and is projected to double from its 1996 level by 2020.

The projections presented in this chapter, while more detailed than those included in earlier issues of the *International Energy Outlook*, nonetheless still reflect a simple framework of analysis (see box on page 119). The key variable for the projections is economic growth, applied to designated modes of transport: road, air, and other (rail, water, and pipeline). The largest component is road transportation. The factors shaping the growth of energy use for road transportation include the motor vehicle population and average use of fuel per vehicle.

Highlights of the *IEO99* projections for transportation are as follows:

- Road vehicles maintain a dominant share (over 70 percent) of transportation energy use throughout the forecast. World growth averages 2.4 percent per year between 1996 and 2020, the same rate as between 1980 and 1996. Road energy use among industrialized nations, however, is expected to grow more slowly than in recent years.

- In the reference case, the world population of road vehicles passes 1.1 billion by 2020—425 million above the level in 1996. The projected increase rivals the 1996 vehicle population of all the industrialized nations combined.

- The most important factor influencing the future size of the world's vehicle fleet is the degree to which developing Asia and Central and South America do in fact undergo rapid motorization. These two regions account for 52 percent of the projected increase in the world vehicle population.

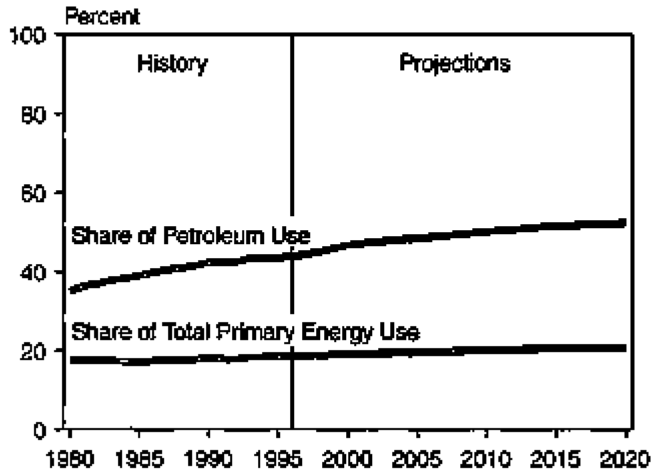
- Fuel consumption for air transportation increases by an average of 3.7 percent per year between 1996 and 2020, compared with 2.3-percent annual growth between 1980 and 1996, and is expected to account for 16 percent of transportation energy use in 2020, up from 12 percent in 1996. Faster growth in fuel use results from an assumed slower rate of improvement in aircraft fuel efficiency, as well as expectations for increasing use of aviation for business and vacation travel.

Transportation's Role in Energy Markets

Two key historical trends are projected to continue in the *IEO99* forecast: transportation's share of total primary energy use shows little increase, while its share of oil consumption grows steadily (Figure 77). These patterns continue for individual countries and regions, and they continue to characterize aggregate world energy markets despite persistent differences in market shares among regions.

[18]Mercosur member nations are Argentina, Brazil, Paraguay, and Uruguay.

Figure 77. World Share of Energy Use for Transportation, 1980-2020



Sources: **History:** Derived from Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

The transportation share of primary energy consumption in industrialized nations is projected to average 26 percent in 2020, up from a 23-percent average share in 1996. Among developing nations the average share is 17 percent in 2020, up from 16 percent in 1996. In the EE/FSU region, where transportation has historically made up a smaller part of total energy use, its share recovers from recent dips but still reaches only 10 percent by 2020.

Total world oil consumption is expected to increase at an average annual rate of 1.8 percent between 1996 and 2020 in the reference case, 25 percent below the rate of increase expected for transportation oil use. Hence, the importance of transportation in oil markets grows, reaching a 51-percent share by 2020 (up from 42 percent in 1996 and 35 percent in 1980). Regional differences are expected to continue, but projected higher demand for transportation services throughout most of the world causes an increase in the transportation share of oil use. An exception is the EE/FSU region, where expected growth in oil use for industrial and building sector energy services almost matches the growth in transportation energy use.

Fuel Mix and Modal Trends

Petroleum products continue to dominate transportation energy use, maintaining a nearly constant 95-percent world market share throughout the forecast. The major petroleum products used in the transportation sector worldwide are motor gasoline, diesel fuel, and jet fuel. Patterns of fuel consumption in the transportation sector vary widely from country to country. For instance, in the United States, gasoline is the dominant petroleum product used to fuel the country's personal-use motor vehicle fleet, whereas in many Western European countries—where gasoline is heavily taxed— diesel fuel use predominates. Indeed, the diesel car share of new car sales in Western Europe grew from 14 percent in 1990 to 22 percent in 1996 [6, p. 13], and *IEO99* projects that European reliance on diesel for road use will remain high, increasing from 46 percent in 1996 to 51 percent in 2020.

In India, diesel fuel use also dominates transportation energy use, but this is attributed to a high reliance on freight travel rather than a penetration of diesel-fueled passenger cars [2, p. 86]. In addition, India's aging coal locomotives are increasingly being replaced by diesel and electric engines with the result that the country's dependence on coal as a transportation fuel declines in the forecast.

Concerns about limiting greenhouse gases add another level of uncertainty to the projections. In the United States and Western Europe there is some debate as to whether stronger penetration of diesel-fueled vehicles should be encouraged as a means of reducing carbon emissions. The U.S. Environmental Protection Agency is expected to finalize its "Tier 2 standards" in 1999, which will require further reductions in emissions of hydrocarbons, carbon monoxide, nitrogen oxides, and particulate matter from light-duty vehicles (passenger cars and light-duty trucks, including sport utility vehicles, minivans, and pickup trucks) beginning with the 2004 model year [7]. Penetration of advanced diesel technology, including a direct injection diesel technology with 50 percent higher fuel efficiency than an equivalent conventional gasoline engine, might reduce carbon emissions by as much as 13 million metric tons in 2020 [8, pp. 1 and 6]. Advanced diesel technology, however, is not a perfect solution to the problem of reducing greenhouse gases. Although the technology is more efficient and could, as a result, reduce carbon emissions, it may also cause unacceptable increases in emissions of nitrogen oxides and particulate matter.

The European Union is also enacting tighter standards on car emissions that might influence future trends in road energy use in Western Europe. The "Euro-III" and "Euro-IV" standards are designed to achieve "cost-effective reductions in emissions through controls on a variety of vehicle types and on fuel quality" [9]. Euro-III standards take effect for new car models in 2000 and for existing cars in 2001; Euro-IV standards will be applied in 2005 and 2006. Many European countries also require motor vehicle owners to pay a vehicle excise tax to encourage people to buy smaller, cleaner cars. In addition, the high motor gasoline taxes levied on European consumers and, to a lesser extent, the fuel efficiency advantages of diesel vehicles have encouraged drivers to rely increasingly on diesel automobiles.

Analysis Assumptions and Approach

Energy projections are inextricably tied to their input assumptions. Some input assumptions, such as gross domestic product (GDP) growth, can be systematically varied to investigate the sensitivity of energy use to alternative economic growth paths. Several analyses of this type are presented in this chapter. Other "inputs" are embedded in the analytical framework of the methodology used to develop the forecast and cannot be readily changed. The influence these assumptions have on the forecast can best be understood by comparing results across different forecasting approaches. The transportation energy forecasts show incremental changes to current energy use patterns in specific countries and for specific transportation modes. In addition, each country's projected energy growth is contingent on exogenous forecasts of economic and population growth.

Methodological assumptions implicit in the approach include:

- *Substitution between transportation modes is not evaluated.* Total transportation energy consumption is the sum of projections made for six modes: road, air, rail, pipeline, inland water, and ocean (bunker). Each mode is evaluated independently on the basis of economic growth assumptions and historical trends in regional transportation energy use. Direct substitution among road, rail, and air is not considered, but relative growth in energy use does vary by mode, resulting in changing modal shares.
- *Among developing regions the configuration of future transportation services follows examples from industrialized nations.* Transportation services available in much of the developing world today remain rudimentary. China, in 1996, had fewer vehicles (including cars, trucks, and buses but not motor bikes) than Texas—less than 10 vehicles per thousand people. Over the forecast, however, per capita income is expected to quadruple in China, motivating increased demand for transportation services. As development proceeds, road and air modal shares are expected to increase while rail's share declines—this is the pattern seen among industrialized nations.
- *Energy prices do not directly affect the forecast.* Energy prices do not appear explicitly in the analytical framework used to develop the transportation forecasts. This was not a judgment about the potential effect that prices may have on transportation energy use. It was a simplifying decision that took into account the likely magnitude of uses in transportation related to economic growth in the context of stable world oil prices.

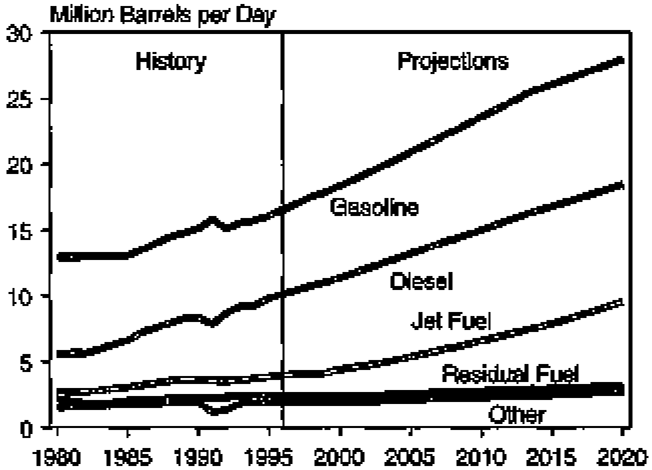
A lack of detailed data for the developing world was the key factor favoring a composite road vehicle approach to the modeling effort. In industrialized nations, studies analyzing road energy use by freight trucks separately from passenger vehicles are routinely done. But most growth is expected in the developing nations, for which the data are far more incomplete. Specifically, data distinguishing fuel use by cars from that by trucks were not available for this analysis, nor were data on annual vehicle usage (miles per year) or energy efficiency (energy per mile) by vehicle type. The data that were available on a consistent historical basis—for total road energy consumption and total registered vehicles [3, 5]—were used as a framework for evaluating the number of road vehicles in operation and the average (composite) fuel use per vehicle per year.

The end-use category "road" in *IEO99* accounts for all road vehicle energy use—by cars as well as freight trucks, utility vehicles as well as buses. Correspondingly, projections linked with road energy, such as vehicle count and vehicle energy intensity (energy use per vehicle per year), refer to an average or composite road vehicle representative of a region's road system. Each region's average vehicle energy intensity reflects its own particular pattern of vehicle mix, efficiency, and usage (travel per vehicle). Changes in vehicle energy intensity over time mirror changes in these factors.

Worldwide, gasoline use averages 2.2-percent annual growth between 1996 and 2020 in the *IEO99* reference case, lower than the annual growth rates projected for jet and diesel fuel (3.7 percent and 2.5 percent, respectively). Accordingly, gasoline's share of total transportation energy use drops from 50 percent to 46 percent, the jet fuel share rises from 12 percent to 17 percent, and diesel's share increases slightly to 26 percent in 2020. Consumption of residual fuel oil, following historical trends, is expected to grow more slowly, and its share of transportation energy use slips to 5 percent by 2020 (Figure 78).

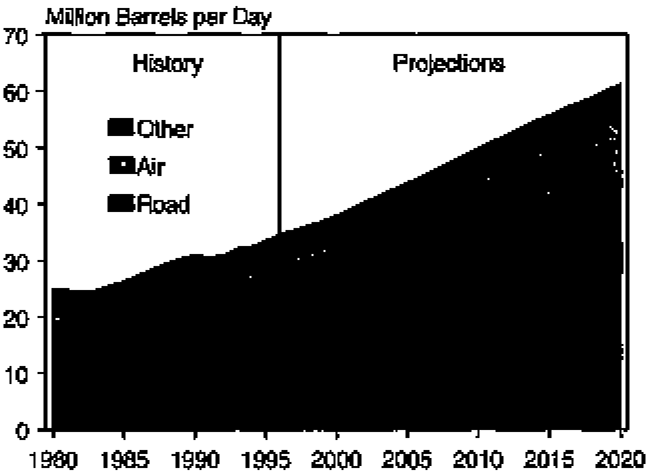
Non-petroleum energy use for transportation (included in "other" in Figure 78) consists mainly of natural gas use in pipelines. Alternative fuels are assumed not to expand their current niche market status in the transportation sector between 1996 and 2020. One significant market for alternative fuels is Brazil, where ethanol derived from agricultural waste is an important source

Figure 78. World Total Transportation Energy Use by Fuel, 1980-2020



Sources: **History:** Derived from Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

Figure 79. World Total Transportation Energy Use by Mode, 1980-2020



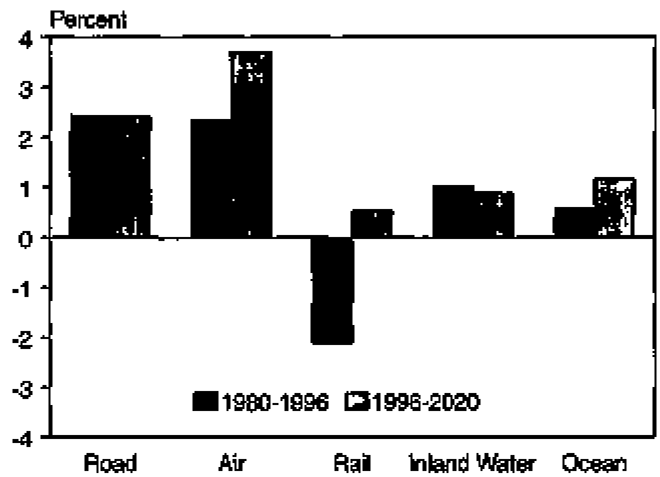
Sources: **History:** Derived from Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

of road energy. Ethanol accounted for one-fifth of total road energy use in Brazil in 1995. This large share is maintained because of a government program started in the 1970s to decrease the country's reliance on imported oil by subsidizing alcohol production from sugar cane (see box on page 122). Although the policy has been scaled back, environmental concerns are expected to increase the use of ethanol as a blending component for gasoline [10].

Road vehicles maintain a dominant share of over 70 percent of transportation energy use throughout the forecast (Figure 79). Worldwide, the growth in energy use by road vehicles averages 2.4 percent per year between 1996 and 2020, the same rate as between 1980 and 1996 (Figure 80). In the industrialized nations, however, road energy use is expected to grow more slowly than in recent years because of slower growth in population and vehicle ownership. Fuel use for air transportation in the industrialized world averages 2.9-percent annual growth between 1996 and 2020, compared with 2.3 percent between 1980 and 1996, and is expected to account for 17 percent of all transportation energy use by 2020, up from 12 percent in 1996. The projected growing per capita incomes among people in the industrialized countries are expected to result in increased long-distance travel by airplane for vacations.

Fuel use for rail transportation shows positive growth in the forecast, reversing recent declines, while fuel use for inland water shipping declines slightly. Ocean transport (bunker) energy use, following long-term growth in international trade, rises at about twice the rate seen in recent years. Pipeline energy use increases only modestly, based on historical trends up to 1996 and pipeline

Figure 80. Growth in World Total Transportation Energy Use by Mode, 1980-1996 and 1996-2020



Sources: **1980-1996:** Derived from Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **1996-2020:** EIA, World Energy Projection System (1999).

projects completed since 1996 or future planned projects. New pipelines may have a major impact on pipeline energy use. For example, the pipeline capacity that came on line in the FSU in 1993 increased world pipeline energy use by 88 percent (318 thousand barrels per day). However, even if pipeline energy use in 2020 increased to three times the level expected in the *IEO99* reference case, it still would make up only 5 percent of total transportation energy use.

Road Energy Use

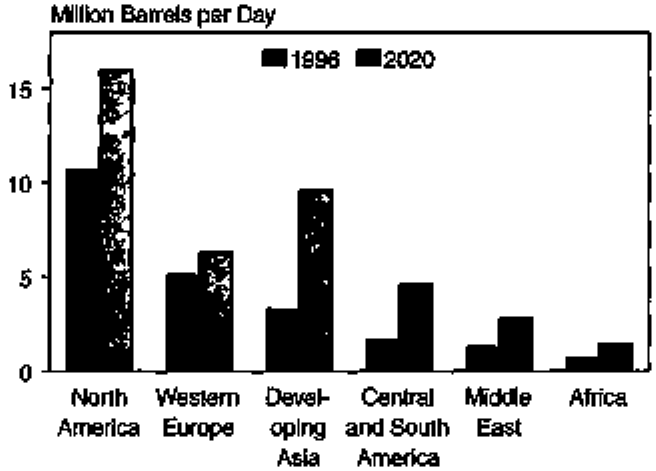
Worldwide, energy use by road vehicles (including cars, freight trucks, utility vehicles, and buses) is expected to increase at an average annual rate of 2.4 percent between 1996 and 2020 in the *IEO99* reference case, reaching 45 million barrels per day by 2020. Rising vehicle ownership rates among developing regions, especially in developing Asia and Central and South America, account for almost two-thirds of the projected increase in road energy use (Figure 81).

In the industrialized regions of North America, Western Europe, and industrialized Asia, road transportation systems are relatively mature, and far slower growth is projected than in developing regions. The road energy share of transportation sector energy consumption in the industrialized nations falls from 61 percent in 1996 to 47 percent in 2020 in the reference case, but in the developing countries it is expected to grow. For developing Asia and Latin America (Mexico and Central and South America), the combined share of road energy consumption reaches 36 percent by 2020, up from a 22-percent share in 1996 (Figure 82). Small increases in the road use share of transportation energy are also expected in the Middle East and Africa.

Clearly, the growth in road energy use will be strongly influenced by the growth in motor vehicle populations. In the reference case projection, the number of road vehicles passes 1.1 billion by 2020—425 million above the level in 1996 (Figure 83). The projected increase rivals the total vehicle fleet of all the industrialized nations combined in 1995. Worldwide, growth in the number of road vehicles is expected to average 2.0 percent per year between 1996 and 2020. The developing nations, however, average 5.0-percent annual growth, and by 2020 they account for 37 percent of the world vehicle stock—nearly twice their 1996 share (Figure 84).

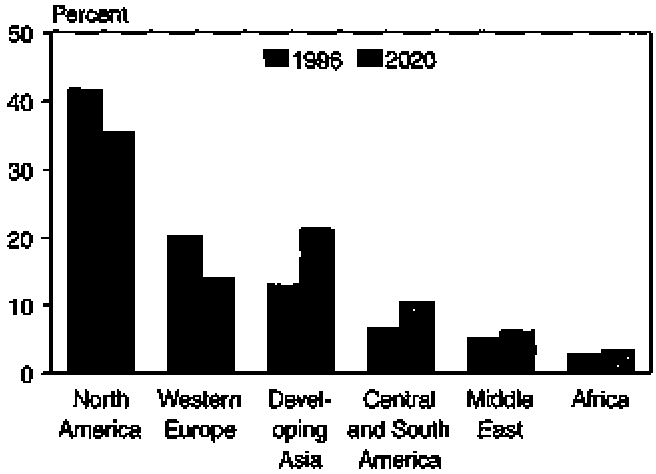
The number of road vehicles in service in a region is estimated by multiplying the region's projected population by an estimate of the extent of its "motorization." Motorization in this context is the total number of road vehicles per thousand people. Motorization levels by country and region fall into two broad categories: mature and emerging. Motorization in the industrialized countries is considered mature. Nations in this

Figure 81. Road Transportation Energy Use by Region, 1996 and 2020



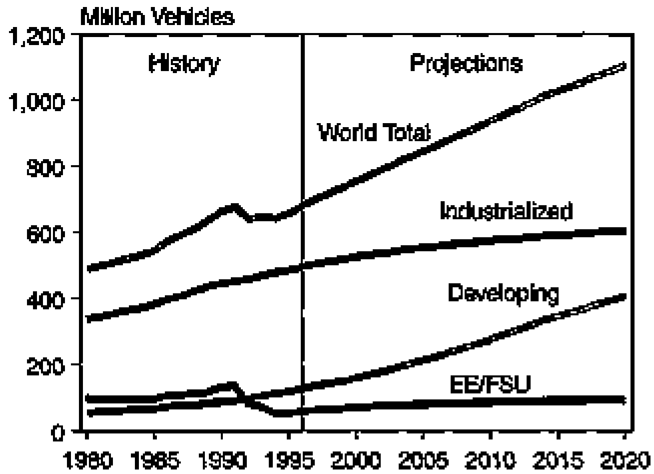
Sources: 1996: Derived from Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). 2020: EIA, World Energy Projection System (1999).

Figure 82. Regional Shares of Road Transportation Energy Use, 1996 and 2020



Sources: 1996: Derived from Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). 2020: EIA, World Energy Projection System (1999).

Figure 83. Road Vehicle Populations by Region, 1960-2020



Sources: History: American Automobile Manufacturers Association, *World Motor Vehicle Data* (Detroit, MI, 1997). Projections: EIA, World Energy Projection System (1999).

Ethanol in Brazil

Brazil has used ethanol derived from biomass as a blending component in gasoline, and in some cases as a neat fuel, since 1931. Brazil has always been heavily dependent on foreign oil. In 1975, oil imports had reached 79.5 percent of total oil demand and 21.1 percent of total imports [11]. After the world oil price increases of the 1970s, Brazil was spending more on imports of crude oil than it was earning from its total exports. The resolution to this problem was to produce more alcohol from sugar cane and develop a new generation of neat-fuel vehicles to consume it.

In 1975, the Brazilian government decided to regulate the ethanol market to increase the production and use of fuel ethanol, creating the Brazilian National Alcohol Program. The National Alcohol Program provided a favorable environment for producers and consumers, guaranteeing that all gasoline sold in the country would be blended with 22 percent anhydrous ethanol, and that the pump price of hydrous ethanol would be competitive with gasoline prices, to entice consumers to buy neat-ethanol cars. (Anhydrous ethanol does not contain water and is used as a blending component for gasoline. Hydrous ethanol is used in neat ethanol cars, which run on 100 percent ethanol.)

In 1975, Brazil's production of ethanol was only 147 million gallons [11]. In the early 1980s, after a financing program of $2 billion, Brazil was producing more than 2.5 billion gallons of alcohol a year, and half of all new cars sold were fitted with alcohol-burning engines. By 1985, alcohol-fueled cars accounted for 92 percent of national automobile sales [12]. By 1988, however, the program was in crisis. Supplies of alcohol became erratic and gasoline prices were falling, but sales of neat ethanol vehicles were higher than had been expected. Consequently, alcohol supplies could not keep pace with demand. The government tried importing methanol as a substitute, but the adverse environmental characteristics of methanol made the government's decision controversial. Ethanol supply was eventually brought into balance with demand at the start of the sugar cane harvest in 1990, but the credibility of the National Alcohol Program had already been severely damaged. Consequently, sales of new neat ethanol vehicles declined sharply. In 1993, only 26 percent of new car sales were alcohol-fueled vehicles [12].

Since 1989 two other factors have affected Brazil's ethanol program. Several large oil fields have been developed offshore and are producing low-cost crude oil. As a result, domestic production of oil has grown considerably, allowing Brazil to become more self-sufficient [12]. Brazil has enough oil reserves to last at least 20 years and plans to boost production [13]. In addition, the use of biomass ethanol has created a serious oversupply of gasoline. The amount of crude oil refined is dictated by the demand for diesel fuel, and because it is not economically feasible to make significant changes in the proportions of diesel, gasoline, liquefied petroleum gases, naphtha, and heating oil derived from crude oil in refineries, gasoline is produced well in excess of demand.

(continued on page 123)

category have modern road and vehicle infrastructure systems. Because their motorization levels are already high, their average motorization rate is projected to increase by only 0.5 percent per year between 1996 and 2020.

Motorization in much of the developing world can be characterized as emerging. These nations have rudimentary road systems and personal travel that is fueled in large part by "person power" (walking or biking). Motorization levels among the developing nations, low at present, are expected to rise rapidly, averaging 3.5-percent annual growth between 1996 and 2020 as strong long-term economic growth, rising per capita incomes, and increasing urbanization lead to increased use of motor vehicles for personal travel. Even at that rate of increase, however, the level of motorization in the developing world is expected to reach only one-tenth the level in the industrialized nations by 2020.

Consistent with recent trends, motorization among the industrialized nations is expected to increase slowly above current levels (Figure 85). In the industrialized world, many countries are expected to reach saturation levels in terms of motorization. The United States and Canada are assumed to reach motorization levels of 800 and 700 vehicles per thousand people in 2020. Even Japan, France, and Germany are expected to reach 650 vehicles per thousand population by the end of the projection period and the United Kingdom about 600.

Some developing countries, including Mexico and Brazil, have already achieved significant levels of motorization, although they are still substantially lower than those of the industrialized world. Historical data on motorization and growth in per capita income in these developing nations guided estimates of future motorization levels. In Mexico, motorization is expected to more than double between 1996 and 2020, rising from 139

Ethanol in Brazil (Continued)

Today, Brazil has 4 million cars that run on neat ethanol, yet fewer than 1 percent of the country's new cars are neat ethanol vehicles, and government incentives for neat ethanol vehicles are being phased out [14]. Total vehicle sales rose to 1.94 million in 1997, from 640,000 in 1989.

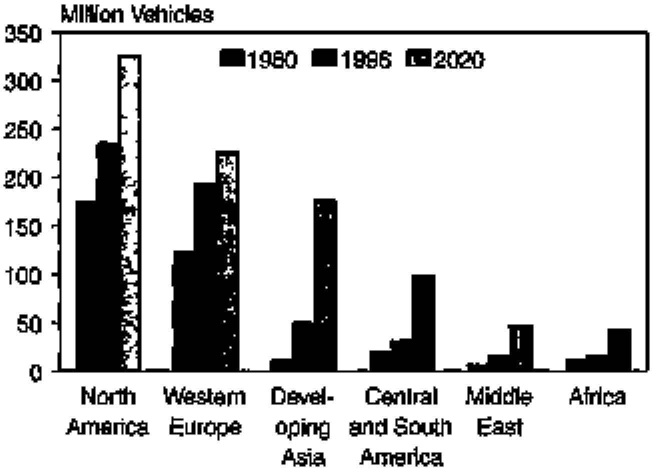
Currently, about 41 percent of Brazil's transportation fuel demand is met with ethanol [11]. The increase in demand for anhydrous ethanol with increasing gasoline consumption has been offset, however, by declining demand for hydrous ethanol, which gasoline is displacing. The overall demand for fuel ethanol has risen from 181,000 barrels of gasoline equivalent per day in 1989 to 206,000 barrels in 1997 (a 1.7-percent annual increase); but anhydrous ethanol production has risen by 23 percent per year since 1990, whereas production of hydrous ethanol has fallen by 0.9 percent per year.

The Brazilian federal government is trying to revitalize its National Alcohol Program, negotiating with governors on incentives for the use of alcohol fuel in bus and taxi fleets. The government is discussing financing arrangements for producers and is also expected to change the distribution system to allow distributors to mix ethanol with gasoline, removing Petrobras, the state oil company, from the process. The current law requires all Brazilian gasoline to be 22 percent ethanol, but it is likely that the percentage will be lowered in the future as the government moves forward with fuel price liberalization [14].

The goals of the new "Proalcool" program will differ from those of the original program, which was created in response to the oil crisis of the 1970s. The decision to revitalize the ethanol program is based on environmental concerns and the number of jobs the sugar cane sector produces. Brazilian legislators want to increase the quantity of ethanol used in fuel to combat Sao Paolo's smog problem and reduce greenhouse gas emissions.

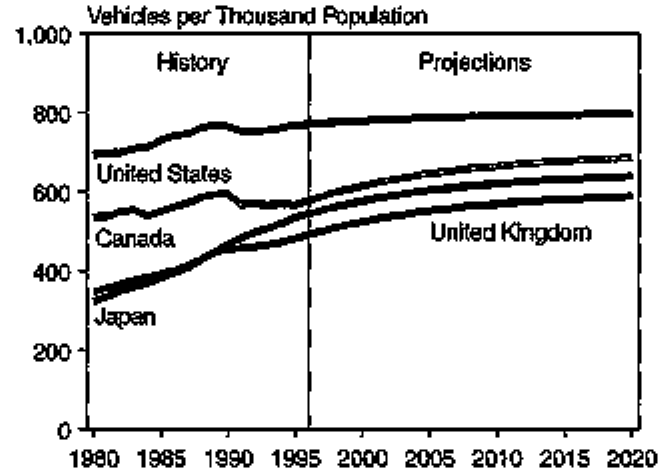
In Brazil, the use of biomass fuel ethanol is an effective mitigation strategy to control greenhouse gas emissions. Normally, the manufacture of crop fertilizers and extraction and purification of ethanol from crops require large amounts of fossil fuel, as do the cultivation and harvest of sugar cane. In Brazil, however, the carbon dioxide emissions balance is favorable, because nearly all the harvesting is done by hand. As a result, fossil fuel inputs are restricted mainly to the agricultural machinery used for land preparation at planting and for transporting the cut cane to mills. The manual harvesting of sugar cane also makes the industry very labor intensive. Sugar cane fields and alcohol factories account for nearly 770,000 jobs a year in the Brazilian economy [13].

Figure 84. Road Vehicle Populations by Region, 1980, 1996, and 2020



Sources: 1980 and 1996: American Automobile Manufacturers Association, *World Motor Vehicle Data* (Detroit, MI, 1997). 2020: EIA, World Energy Projection System (1999).

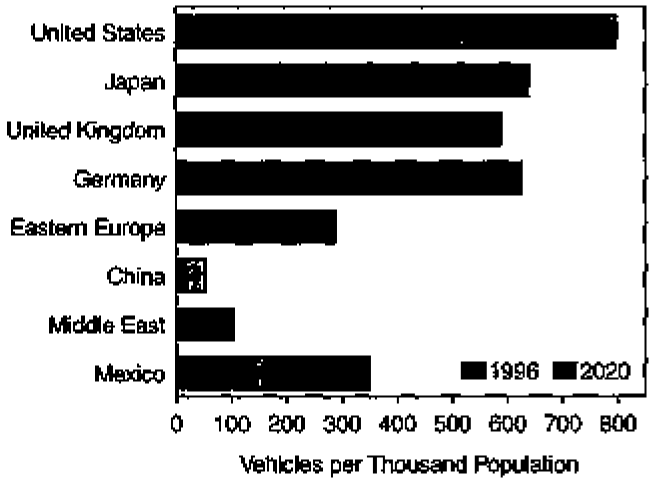
Figure 85. Motorization Trends in Industrialized Countries, 1980-2020



Sources: **History:** American Automobile Manufacturers Association, *World Motor Vehicle Data* (Detroit, MI, 1997). **Projections:** EIA, World Energy Projection System (1999).

vehicles per thousand people in 1996 to 438 vehicles per thousand people in 2020 (Figure 86). The Latin American countries, in general, have higher vehicle ownership rates than many other developing countries, based on their higher per capita incomes, high levels of urbanization, historically low subsidized prices for transportation fuels throughout the region, and the large distances separating cities [1, p. 354].

Figure 86. Motorization Rates, 1996 and 2020



Sources: **1996:** American Automobile Manufacturers Association, *World Motor Vehicle Data* (Detroit, MI, 1997). **2020:** EIA, World Energy Projection System (1999).

Several developing Asian countries have also achieved fairly high motorization levels. South Korea is projected to reach a motorization level of 450 vehicles per thousand people by 2020, up from 207 in 1996. There has been substantial growth in motorization in South Korea over the past decades. Since 1980—when there were an estimated 14 vehicles per thousand people—motorization has grown by an average of 18.4 percent per year. This trend is expected to continue through the projection period as the motorization level approaches that of the industrialized countries of Western Europe.

For those developing Asian countries that had barely begun providing wide-scale road transportation services by 1996 (China, India, and other developing Asia), motorization levels are expected to remain low throughout the projection period, despite robust projected growth. In China, the number of motor vehicles per thousand people is projected to increase by 7.6 percent annually between 1996 and 2020, but motorization increases only from 9 to 54 vehicles per thousand people—less than one-fourteenth the current U.S. level.

In the Middle East, vehicle ownership is expected to grow by 2.7 percent per year over the projection period, rising from 55 to 103 vehicles per thousand people between 1996 and 2020. Motorization levels in the Middle East are not expected to approach those of industrialized countries, such as France, Germany, or Japan. One reason for the slow projected growth in car ownership in the Middle East is that in some of the countries women are actively discouraged from driving, ultimately limiting the fraction of the population that will own cars [2, p. 399]. Another reason for the lower motorization rates in this region is the age distribution of the population in some countries. In Saudi Arabia, for example, Standard & Poor's DRI has estimated that there are currently about 90 vehicles per thousand people [15, p. 240], despite the fact that 60 percent of the population is under the age of 20.

Vehicle Energy Intensity

Energy projections for a road vehicle that is a composite representation of all road vehicles implicitly include assumptions about the future mix of vehicles and their individual usage and efficiency characteristics. Because a freight truck's annual fuel consumption may easily equal that of 30 passenger cars, these assumptions are critical to the energy forecast. For developing countries, major changes in average vehicle characteristics mark the transformation of a nation's road system from one dominated by inefficient trucks driving long hours on poor roads to one increasingly focused on personal passenger vehicles. Not surprisingly, the assumptions made about vehicle energy intensity for developing nations differ from those for industrialized nations. In each case, however, projected trends follow smoothly from historical data.

Projections of vehicle energy intensity (energy use per vehicle per year) are based on an analysis of historical trends in both industrialized and developing countries. Three observations from the analysis shaped the methodology used to project changes in energy intensity for each country's average road vehicle:

- Annual fuel use per vehicle is consistently higher in developing regions than in the industrialized nations.
- Among developing nations vehicle energy intensity has declined as economic development has progressed.
- Among industrialized countries remarkably little change in energy intensity has taken place over the past decade.

Among the industrialized nations, data categorized by vehicle type (freight truck, passenger car, and commercial size van) commonly include vehicle registrations and travel as well as fuel consumption. Average energy intensity is generally a derived estimate calculated as the quotient of fuel use per vehicle per year and miles traveled per vehicle per year. Where available, such data are the foundation for energy projections by vehicle use category. They define a starting point for analysis and a benchmark against which projections can be measured.

For the developing nations (where most growth is expected) data on the total number of registered vehicles and total road energy use are often available, information about vehicle mix (freight truck versus passenger car) and use patterns of vehicles is limited, and data on fuel use by vehicle type are practically nonexistent.

In industrialized countries little change is expected in each country's annual fuel consumption per vehicle, as projected increases in vehicle travel are nearly balanced by increases in vehicle efficiency (Figures 87 and 88). Vehicle energy intensities also continue practically unchanged over the forecast. The United States and Canada maintain average vehicle fuel consumption rates of 19 and 15 barrels per year, respectively, throughout the forecast, roughly 60 percent higher than the rate in Western Europe and 100 percent higher than the rate in Japan. Higher vehicle efficiencies in Western Europe and Japan explain some of the difference, but factors that affect annual vehicle travel—such as land area, population density, and the spatial distribution of employment and consumer services relative to residences—are more significant. Such differences are unlikely to change appreciably over the forecast period.

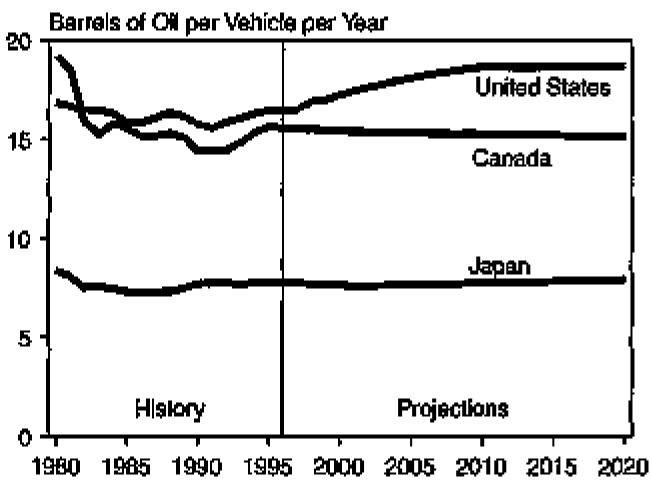
Given that the data refer to a composite representation of all road vehicles, the near constancy of each industrialized nation's vehicle energy intensity is striking—1995 values differ from those in 1985 by only a few percent, and no trend is apparent. The mature economies of the industrialized nations appear to have reached a stage at which changes in the mix, usage, and age distribution of vehicles no longer significantly influence changes in average vehicle energy intensity. In the reference case, vehicle efficiency improvements almost completely offset increased travel per vehicle, a trend consistent with historical experience over the past decade.

Vehicle energy intensities in developing regions, unlike those in the industrialized nations, have declined over the past decade. Declines continue in the forecast, but annual fuel use per vehicle remains higher than in industrialized countries (Figure 89). In the absence of data on vehicle travel and efficiency it was assumed that improved car and truck efficiency probably played a relatively minor role in declining energy intensity in developing nations between 1985 and 1995, and that changes in vehicle mix, in car and truck usage (miles per year), and in car and truck age and size distribution were and will continue to be important determinants of vehicle energy intensity. The development experience of South Korea and other nations was the basis for projections of continued declines in vehicle energy intensity (Figure 90).

Air Transportation

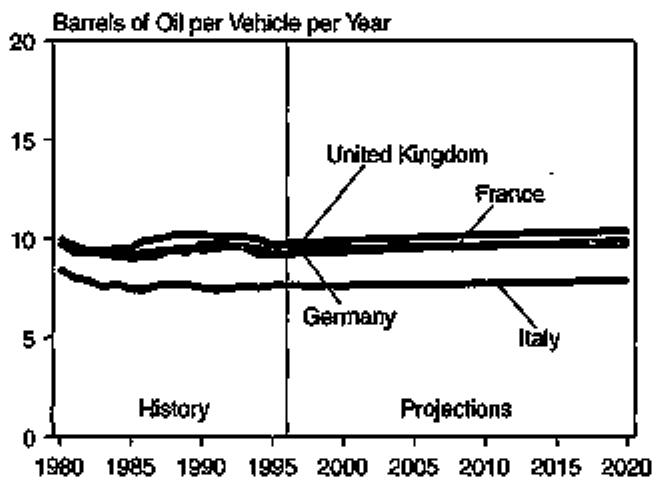
Worldwide, energy use for air transportation is expected to grow faster than for any other transport mode between 1996 and 2020, with total consumption increasing by nearly 6 million barrels per day or 140 percent (Figure 91). As a result, the aviation share of total transportation energy use increases from 12 percent in 1996 to 17 percent in 2020. Total energy use for air transportation is expected to increase at an annual rate of 3.7 percent per year between 1996 and 2020—much faster than

Figure 87. Vehicle Energy Intensity in Industrialized Countries, 1980-2020



Sources: **History:** Derived from Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998), and American Automobile Manufacturers Association, *World Motor Vehicle Data* (Detroit, MI, 1997). **Projections:** EIA, World Energy Projection System (1999).

Figure 88. Vehicle Energy Intensity in Western European Countries, 1980-2020

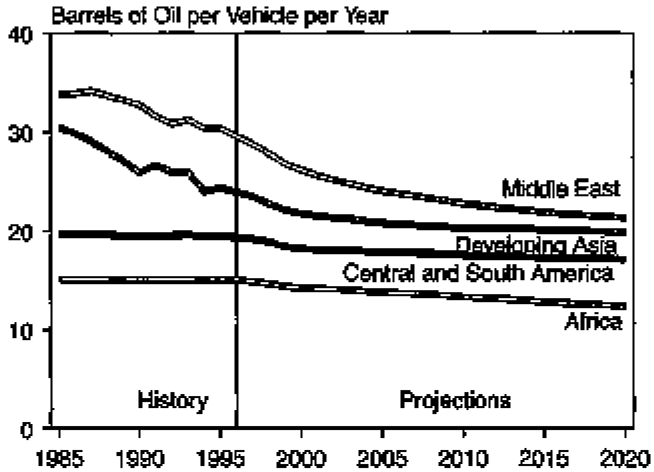


Sources: **History:** Derived from Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998), and American Automobile Manufacturers Association, *World Motor Vehicle Data* (Detroit, MI, 1997). **Projections:** EIA, World Energy Projection System (1999).

between 1980 and 1996. Air travel is expected to increase worldwide, because projected growth in per capita income will increasingly allow people to afford air travel. In addition, aircraft and system efficiency improvements (energy use per seat mile traveled) are expected to proceed at a much slower pace than in the past. The kinds of efficiency gains achieved with the introduction of high-bypass turbofan engines and wide-body aircraft are unlikely to be duplicated in the forecast period. On a regional basis, percentage increases in air transportation energy between 1996 and 2020 reflect regional economic growth rates (Figure 92).

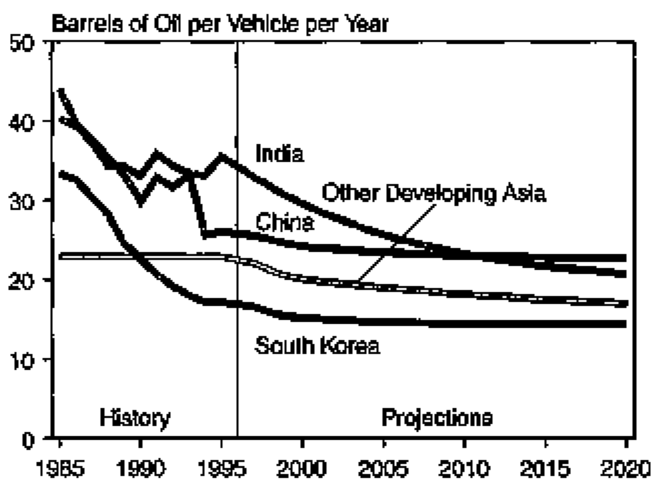
Air transportation energy use in the industrialized countries is expected to grow by only 2.9 percent per year over the projection period, because the infrastructure supporting air travel in the industrialized world is well established. Air transportation energy use among developing countries is expected to grow at roughly twice the rate for industrialized nations, as strong long-term economic growth, particularly in the

Figure 89. Vehicle Energy Intensity in Developing Regions, 1985-2020



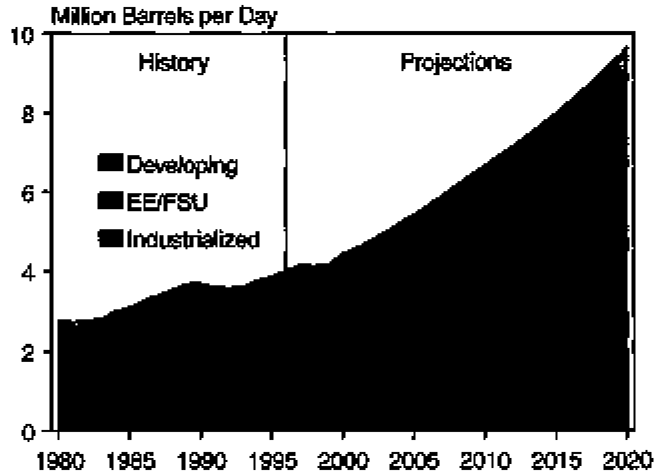
Sources: **History:** Derived from Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998), and American Automobile Manufacturers Association, *World Motor Vehicle Data* (Detroit, MI, 1997). **Projections:** EIA, World Energy Projection System (1999).

Figure 90. Vehicle Energy Intensity in Developing Asia, 1985-2020



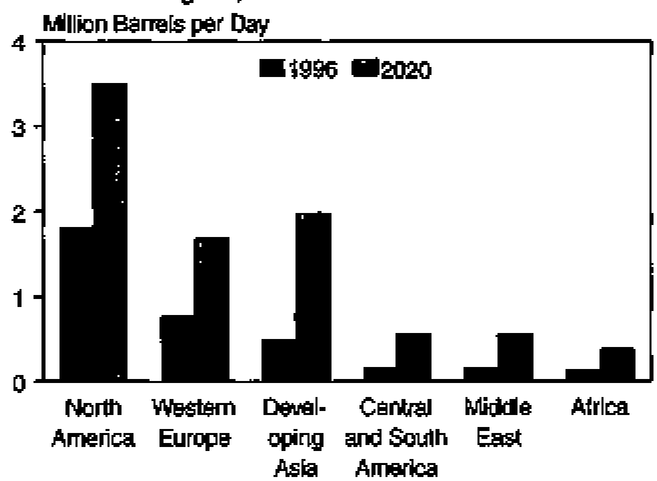
Sources: **History:** Derived from Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998), and American Automobile Manufacturers Association, *World Motor Vehicle Data* (Detroit, MI, 1997). **Projections:** EIA, World Energy Projection System (1999).

Figure 91. Air Transportation Energy Use by Region, 1980-2020



Sources: **History:** Derived from Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

Figure 92. Air Transportation Energy Use by Region, 1996 and 2020

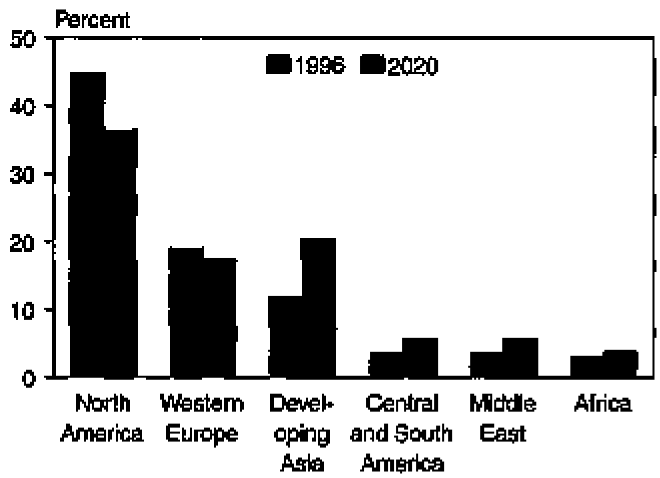


Sources: **1996:** Derived from Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **2020:** EIA, World Energy Projection System (1999).

countries of developing Asia and Central and South America, fuels an expansion in air travel. In the EE/FSU region, estimates for air travel energy demand closely track the expected slow path of economic recovery, and energy consumption for air travel remains below the peak levels achieved in the late 1980s.

In developing Asia, strong growth in air transportation energy use is expected, with an average annual growth rate of 6.1 percent between 1996 and 2020. The air transportation share of total transportation energy consumption in developing Asia rises from 10 percent in 1996 to 15 percent in 2020 (Figure 93), when energy use for air travel is projected to surpass the 1996 total for North America. In many developing Asian countries, the airline infrastructure is far less extensive than that in the industrialized world. In China, for instance, there are only 192 airports with paved runways, whereas in the United States—which is roughly the same geographic size as China—there are 5,167 airports with paved runways [16]. Continued economic growth in the countries of developing Asia will require improved access to air travel.

Figure 93. Regional Shares of Total Air Transportation Energy Use, 1996 and 2020



Sources: **1996:** Derived from Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **2020:** EIA, World Energy Projection System (1999).

The use of energy for air travel in Central and South America is projected to grow by 5.7 percent annually between 1996 and 2020, more than tripling to 558 thousand barrels per day. The infrastructure needed to support growing air travel varies widely among the countries of this region. The larger economies of Argentina, Brazil, Chile, and Venezuela have well-established airport facilities. In 1996, Argentina's airports handled some 12 million passengers, Chile's 2 million, and Venezuela's Simón Bolívar International Airport more than 6 million [4, pp. 32, 88, and 207]. Brazil's airline system connects most of the regions of the country, as well as major cities worldwide. In contrast, Peru and Colombia have relatively rudimentary airport facilities. Colombia has more than 1,000 airports, but only 60 percent of them have paved runways and only a few have the facilities to accept large-capacity cargo planes [4, p. 116]. Expanding tourism—resulting from stable currencies and improved economic conditions—is expected to support the growth of the air industry throughout the region. Further, in some countries, such as Venezuela, air freight transportation is expected to increase strongly, encouraged by the growing presence of foreign firms [4, p. 207].

Other Transportation Modes

Projections of energy use for rail transportation, inland water shipping, ocean shipping, and pipeline are based on historical energy consumption trends relative to historical GDP growth trends. These transportation modes are expected to account for a decreasing share of world transportation energy use as road (including freight trucks) and air transportation expand. Combined, the "other" transportation modes are expected to account for 12 percent of transportation energy use in 2020, down from a 17-percent share in 1996 and a 22-percent share in 1980.

Declining shares of transportation energy consumption do not indicate that rail and waterborne modes are declining in importance, in terms of either the volume or value of freight movement. Worldwide, energy use for these other forms of transportation is projected to increase from 5.1 thousand barrels of oil per day in 1996 to 6.5 thousand barrels per day in 2020. Freight modes remain vital to the commerce of many commodities and to growth in world trade. The projections for pipeline energy use are based on limited historical experience. Few nations have 1995 energy consumption data for this category.

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Environmental Issues and World Energy Use

In the coming decades, global environmental issues could significantly affect patterns of energy use around the world. This chapter examines the factors that govern national levels of energy-related carbon emissions.

In recent years, the principal international energy issues have shifted from supply interruptions and their implications for energy security and price stability to the impact of energy production and consumption on regional and global environments. Frequently, regional and global environmental goals are in conflict. For example, nuclear or hydropower energy projects may be opposed within a given country, while on a global scale they lessen emissions of carbon dioxide—the principal greenhouse gas. Although the focus of this analysis is on global environmental issues such as climate change, it should be understood that local environmental concerns and political decisions based on them may affect the ability of the world community to meet global environmental goals. In the coming decades, global environmental issues and their policy implications could significantly affect patterns of energy use.

The challenges of energy use and environmental quality facing the industrialized countries differ from those for the developing world. The industrialized countries have predicated their economic development on the availability of relatively low-cost fossil fuels. Accordingly, the infrastructure has been built to accommodate private vehicle travel and single-family dwelling units with relatively large amounts of space per person, especially in North America. Given the amount of capital investment in place, policies that modify underlying sources of energy inputs and end-use patterns will require time for turnover of existing capital stock if potentially large economic displacements are to be avoided. The principal challenge then, to the industrialized countries, is to implement policies that protect the global environment while allowing for flexible adjustment of their energy systems.

The developing world, while seeking to grow economically, is confronted with the environmental lessons learned in the process of the economic growth achieved by the industrialized countries. Within developing countries, much of the infrastructure that would support an industrialized economy is not yet in place. This presents an advantage in terms of identifying development paths that will allow greater scope for alternative energy sources and patterns of end-use consumption as new capital stock is put in place. On the other hand, developing economies are not likely to adopt policies that encourage alternative patterns of energy production and consumption if there is the perception that such policies are more costly and undermine near-term growth objectives.

This chapter examines the link between energy use and emissions of carbon dioxide in the context of the *International Energy Outlook 1999* (*IEO99*) baseline projections and in light of possible greenhouse gas initiatives and reduction scenarios such as those proposed under the Kyoto Protocol. Implications are examined for the industrialized Annex I countries in terms of what combinations of energy intensity and carbon intensity reductions would be required to reduce carbon emissions.

Highlights of this chapter include:

- Levels of energy-related carbon emissions depend on economic growth, the amount of energy consumed per unit of economic activity, and the mix of nonfossil and fossil fuel sources used to produce energy for end-use consumption.
- If carbon emissions are to be stabilized or reduced worldwide, there must be declines in energy intensity as well as substitution of less carbon-intensive fuels for more carbon-intensive fuels.
- Not all industrialized Annex I countries are in equal positions with regard to carbon reduction scenarios. They differ in energy intensity, the carbon intensity of fuels used to meet energy demand, and the availability of low-carbon or noncarbon fuels for future energy supplies.
- Replacement of existing nuclear capacity with a suitable non-carbon-emitting energy source could pose a challenge to the ability of many of the industrialized Annex I countries to reduce and stabilize carbon emissions.
- The degree of flexibility built into any carbon reduction approach, through mechanisms such as trading of carbon credits, could have a substantial effect on the feasibility of achieving implementation. Additionally, the amount of credits potentially available from the transitional economies of Eastern Europe and the former Soviet Union (EE/FSU) has been revised upwards because of changes to economic growth projections for the FSU and because the Kyoto Protocol targets for Eastern Europe in *IEO99*

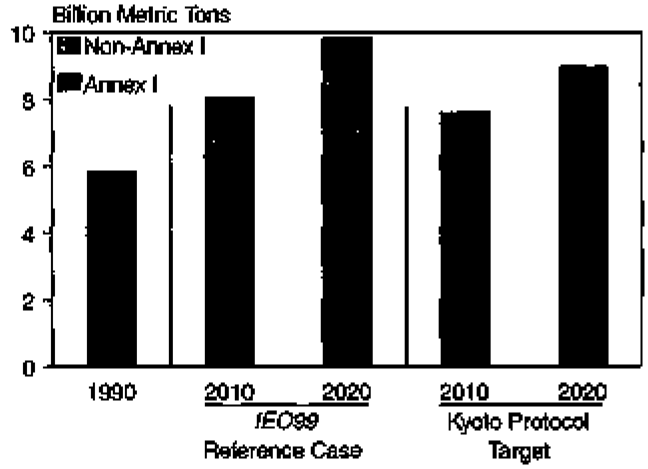
have been recalculated to reflect the fact that some countries in Eastern Europe have opted to use base years other than 1990.

The Framework Convention on Climate Change

The focus of international debate in recent years has been the Framework Convention on Climate Change developed in Rio de Janeiro, Brazil, in 1992; the resulting Protocol developed in Kyoto, Japan; and the Conference of the Parties (COP-4) held in Buenos Aires, Argentina, in the first 2 weeks of November 1998—all under the auspices of the United Nations Intergovernmental Panel on Climate Change [1]. The Kyoto Protocol agreement, if ratified, calls for quantifiable goals for carbon emissions from the Annex I countries (Table 20). Although it is difficult to predict the outcome of such broad-reaching international agreements, it is helpful to study the underlying factors that contribute to energy-related emissions of carbon dioxide.

The Kyoto Protocol, while calling for substantial cuts in carbon emissions by Annex I countries, will not mean stabilization of carbon emissions on a global basis (Figure 94). Without the Kyoto agreement, emissions are projected to increase by 38 percent between 1990 and 2010; if the agreement goes into effect, they are projected to increase by 31 percent. In the long term, carbon stabilization will require participation by the world's developing nations.

Figure 94. Carbon Emissions by Annex I and Non-Annex I Nations in Two Cases, 1990, 2010, and 2020



Sources: 1990: Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

The so-called "clean development mechanism" (CDM) may offer developing nations participation under the Kyoto Protocol. Under the CDM, projects undertaken by Annex I nations to reduce emissions in developing

Table 20. Projected Effects of the Kyoto Protocol on Carbon Emissions in Annex I Countries, 2010

Region and Country	Carbon Emissions (Million Metric Tons) 1990	2010, *IEO99* Reference Case	2010, Kyoto Protocol Target	Change From *IEO99* Reference Case, 2010 (Million Metric Tons)	Change From 1990 Emissions (Percent)	Change From *IEO99* Reference Case, 2010 (Percent)
Annex I Industrialized Countries						
North America	1,472	1,952	1,370	-582	-7	-30
United States	1,346	1,790	1,252	-538	-7	-30
Canada	126	162	118	-44	-6	-27
Western Europe	936	1,021	862	-160	-8	-16
Industrialized Asia	364	435	354	-81	-3	-19
Japan	274	322	258	-64	-6	-20
Australasia	90	113	97	-16	7	-14
Total Annex I Industrialized	2,772	3,408	2,586	-822	-7	-24
Transitional (EE/FSU)[a]						
Former Soviet Union	991	666	990	324	0	49
Eastern Europe	299	270	320	50	7	18
Total EE/FSU	1,290	935	1,309	374	1	40
Total	4,062	4,344	3,895	-449	-4	-10

[a]Annex I countries currently account for 83 percent of FSU carbon emissions, 94 percent of Eastern Europe's carbon emissions, and 86 percent of the total for the EE/FSU region.

Sources: **1990:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

countries could be counted toward Annex I country goals. Thus, the CDM may provide a way to fund sustainable energy projects in developing countries.

The following discussion focuses on the industrialized Annex I countries. They are grouped into three categories: North America, which consists of the United States and Canada (Mexico is not an Annex I country); Western Europe; and industrialized Asia, which consists of Japan, Australia, and New Zealand. The transitional Annex I countries in the EE/FSU region are projected to generate net carbon credits in relation to Kyoto Protocol goals. Current estimates indicate that credits for the equivalent of 374 million metric tons of carbon emissions would be available from the EE/FSU countries, nearly double last year's estimate of 196 million metric tons. The Kyoto targets for Bulgaria, Hungary, Poland, and Romania—which currently account for some 66 percent of all emissions from Eastern European countries—were recalculated in this year's *IEO* to reflect Article 3.5 of the Protocol, which allows the four countries to use base years other than 1990. Bulgaria and Romania are using 1989 as a base year; Poland is using 1988; and Hungary is using the average emissions for the years 1985 to 1987. As a result, the Kyoto target for total carbon emissions for Eastern Europe in 2010 is 320 million tons in IEO99, up from 277 million metric tons in the *International Energy Outlook 1998* (*IEO98*), freeing the difference as possible emissions credits. The rest of the increase in the estimate of available credits is accounted for by changes in the economic outlook and expected mix of energy fuel use in the FSU region.

The reduction in expected energy consumption for the FSU region in this year's projections could substantially change the amount of effort required by the Annex I countries as a whole to meet their Kyoto Protocol targets. In *IEO98*, energy demand in the FSU was expected to recover to its 1990 level by the end of the projection period. Carbon emissions were also expected to rise, but they remained below the 1990 level because the recovery featured increases in the use of less carbon-intensive natural gas rather than more carbon-intensive coal. As a result, *IEO98* projected that in 2010 credits available from the FSU would contribute 199 million metric tons to the total of 822 million metric tons that the industrialized Annex I countries would need to eliminate from the baseline projection to meet the Annex I targets. In this year's projection, however, the potential contribution in 2010 from the FSU has increased by 62 percent, to 324 million metric tons.

In *IEO99*, the credits projected to be generated from the transitional economies represent 45 percent of the total emissions reductions that would be required to meet the Kyoto targets if they are ratified—up from the 21 percent estimated in *IEO98*. In addition to the reasons described above, the increase is the result of adjustments that changed the 1990 baseline emissions for the EE/FSU region, the 2010 projections, and the resulting Kyoto targets for the EE/FSU nations.

The economic collapse in Russia has meant reductions from the *IEO98* projections of FSU fossil fuel use in 2010: 21 percent for oil, 10 percent for natural gas, and 22 percent for coal. *IEO99* projects that, by 2010, the resulting emissions from this lowered outlook for fossil fuel use in the FSU reach only 666 million metric tons, nearly 16 percent less than projected in *IEO98*. Because the transitional Annex I countries currently account for about 86 percent of the EE/FSU region's total emissions, much of the projected emissions reduction could be used as tradable emissions units with the industrialized Annex I countries as they attempt to meet Kyoto Protocol emissions targets. Accordingly, to meet their Kyoto Protocol targets, Annex I countries would need to reduce emissions by 10 percent from the reference case projection rather than by 16 percent as reported in *IEO98*. Indeed, emissions are expected to grow by 7 percent between 1990 and 2010 in the industrialized Annex I countries and the EE/FSU combined, because the 27-percent decrease in emissions expected for the EE/FSU offsets the 23-percent increase projected for the industrialized Annex I countries.

Factors Contributing to Energy-Related Carbon Dioxide Emissions

Two factors, in combination with the level of economic activity, determine the energy-related carbon dioxide emissions of a given country at a given point in time. Differences in these factors from one country or region to the next determine the amount of emissions, their sources, and the relative baseline position from which a country could move to carbon reduction and stabilization.

- **Energy Intensity.** Energy intensity is a measure of the output of an economy in relationship to its energy inputs. Energy intensity within an economy is influenced by the energy efficiency of existing capital stock, such as electricity generation facilities, end-use equipment, and vehicles. The energy efficiency of the capital stock is in turn influenced by the relative prices of energy and other inputs to the economy, such as capital and labor. The more expensive energy is in relation to other inputs, the more incentive there is to invest in energy-efficient technologies and in the research and development that leads to efficiency improvements. Conversely, if energy prices decline and remain low, there is less incentive for research and development or investment in energy-efficient technologies. If energy is a large portion of a consumer's budget, there is a greater incentive to pay attention to energy costs.

For example, in the carbon reduction cases used for the analysis reported in the Energy Information Administration (EIA) report, *Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity* [2], where energy costs were higher than in the reference case, the fuel economy of newly purchased light-duty vehicles in 2010 was expected to be higher also (see detailed discussion on pages 135-137 below). Because higher fuel prices are expected to encourage the development of advanced fuel-saving technologies, the average fuel efficiency for all new cars in 2010—projected to be 30.6 miles per gallon in the reference case—ranged from 32.0 miles gallon to 36.4 miles per gallon in the carbon reduction cases. Higher fuel prices would provide automobile manufacturers with incentives to achieve more rapid advances in technology and apply them to new vehicles. Consumers would also place a higher value on fuel economy, because higher fuel prices would mean shorter payback periods for their investments in more efficient vehicles.

A factor called the "autonomous rate" of energy use accounts for those changes in energy intensity that are not attributable to price effects. The sources of such change include shifts from energy-intensive to less energy-intensive industries; changes in technology affecting use rates of energy in a range of energy applications; and changes in the composition of world trade. Other factors that can influence energy intensity include changes in standards for energy-using appliances and equipment. Such changes, while not reflected in the price of the energy commodity, are not without costs and can have consequences that are the reverse of their intended results. Changes in tastes and preferences where, for example, people bicycle to work when they could afford to drive, also influence the energy intensity of an economy and are reflected in the autonomous rate of energy use. In sum, many factors can influence energy intensity. Indeed, even without the pursuit of specific energy policies, energy intensities have been trending down gradually in developed countries while energy prices have fallen.

- **Carbon Intensity of Energy Supply.** Carbon intensity is a measure of the amount of carbon used per unit of energy produced. Because energy produced from nuclear power plants and from most renewable facilities (wind, solar, and hydropower) emit no carbon and the carbon content of fossil fuels varies, fuel choice makes a significant difference in terms of the amount of carbon dioxide emitted in meeting energy demand. Coal emits the largest amount of carbon per unit of energy output, petroleum the next largest, and natural gas the least of the fossil fuels. In the analysis described below, based on the U.S. economy, fuel switching would contribute the most to meeting the hypothetical U.S. emissions reduction goals [2].

Components of Energy-Related Carbon Emissions

A more formal perspective on the components of carbon emissions levels is provided by the following simple equation, where total energy-related carbon (C) is equal to the ratio of carbon to energy (C/E) times the ratio of energy to gross domestic product (E/GDP) times GDP [3]:

$$C = (C / E) \times (E / GDP) \times GDP \quad .$$

Clearly, government policy is not formed with the intention of reducing a country's GDP. The primary goal of carbon reduction policy, therefore, is one of constraining carbon emissions while minimizing adverse affects on GDP growth.

As a result of the petroleum supply disruptions and price spikes of the 1970s, energy intensity has dropped consistently among most of the industrialized nations. The continuing decrease projected in the *IEO99* reference case is based on an expected shift away from heavy industry toward information-based service economies and the adoption of inherently more efficient technologies, even in the face of stable energy prices.

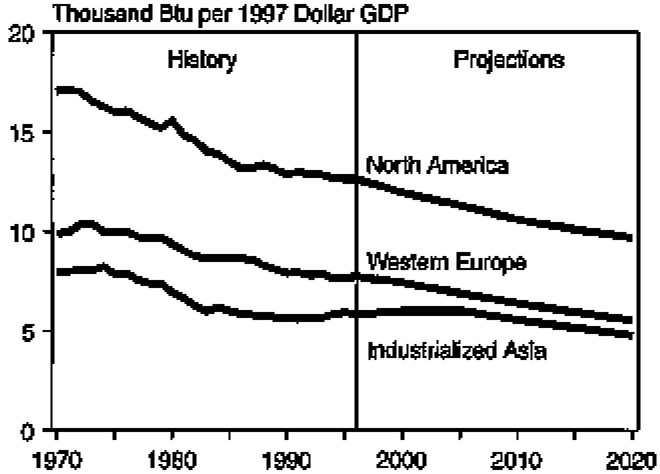
Although there has been incentive in the past to reduce energy intensity, there has been little incentive to reduce carbon intensity. Until recently, carbon dioxide has been viewed as a benign presence in the atmosphere, and there have been no costs associated with carbon emissions. What changes have taken place have been the result of changes in technology, such as the introduction of nuclear power, or market forces, such as the emergence of natural gas as a competitive fuel for electricity generation. Increasing the use of low-carbon or carbon-free energy sources may require costly long-term changes to the energy infrastructure, but there is little chance of stabilizing carbon emissions without them.

The remainder of this chapter examines energy-related carbon dioxide emissions from the industrialized Annex I countries. Possible reduction scenarios are examined in the context of total energy demand and fuel mix and their implications for energy and carbon intensity.

Energy Intensity of Industrialized Countries

Energy intensity differs from one region to the next in the industrialized world (Figure 95). The differences result from many factors, such as population density, weather, existing infrastructure, availability of energy supply, taxation, and cultural tastes and preferences.

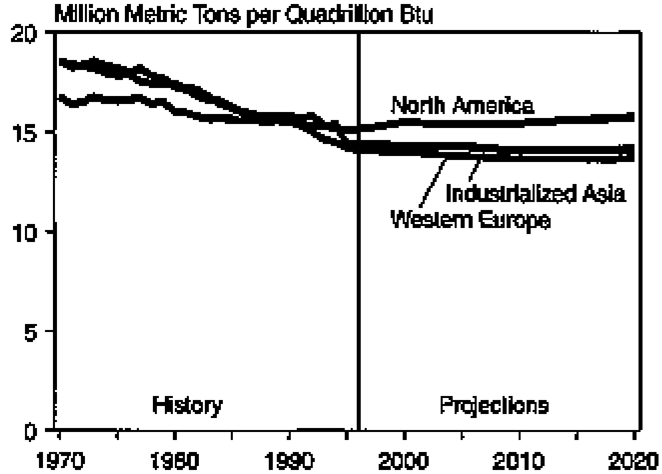
Figure 95. Energy Intensity in Industrialized Nations by Region, 1970-2020



Note: North America does not include Mexico.

Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

Figure 96. Carbon Intensity in Industrialized Nations by Region, 1970-2020



Note: North America does not include Mexico.

Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

North America's energy intensity—the highest in the industrialized world—is more than twice that of industrialized Asia. Energy intensity in North America dropped sharply in the 1980s following the price increases of the late 1970s and early 1980s, and it is projected to continue dropping as the economy grows more rapidly than energy demand. The energy intensity of the industrialized Annex I countries is projected to decline by about 24 percent between 1996 and 2020 in the *IEO99* reference case. Without such a decline, projected energy requirements would rise by about 135 quadrillion British thermal units (Btu), as compared with the projected rise of 55 quadrillion Btu, between 1996 and 2020.

Carbon Intensity of Industrialized Countries

Carbon intensity also differs across regions and over time (Figure 96); however, the differences tend to be smaller than the differences in energy intensity, inasmuch as fossil fuels are a ubiquitous energy source throughout the world. Before 1990, the carbon intensity for North America was the lowest of the industrialized regions. From 1990 to 1995, however, coal became a less important energy source in Western Europe with the shutting down of lignite production in Germany and hard coal production in the United Kingdom, even as productivity gains in the U.S. coal industry made coal a relatively inexpensive fuel for U.S. electricity generation [4]. As a result, North America had the highest carbon intensity among the industrialized regions, a circumstance that is expected to continue through 2020. A further problem with regard to carbon intensity in the United States is the expected loss of nuclear generation capacity, which at this point is likely to be replaced by fossil fuel generation.

The carbon intensity for Western Europe, which was just slightly more than that for North America in 1990, has dropped in recent years and is projected to stay below 14 million metric tons per quadrillion Btu of energy produced, as significant amounts of coal use are replaced by natural gas and by nuclear power, particularly in France. On the other hand, a reversal in the current trend of declining energy intensity in Western Europe is possible, as Sweden and Germany are leaning toward early nuclear retirements [5]. If a significant amount of Europe's nuclear capacity is retired early, reductions in carbon intensity will become more difficult.

Industrialized Asia has shown, and is projected to show, a carbon intensity similar to that for Western Europe, stabilizing at about 14 million metric tons per quadrillion Btu. Japan is somewhat limited in its ability to expand natural gas use due to the relatively high cost of liquefied natural gas.[19] The main source of non-carbon-emitting energy in Japan is nuclear power, which is projected to increase.

In all major regions of the industrialized world, nuclear power plays an important role in keeping carbon intensities below what they would be otherwise. However, of the industrialized Annex I countries, political and economic pressures have prevented any new nuclear capacity from being built outside France and Japan. It remains to be seen how climate change policy will affect the prognosis for the nuclear industry worldwide.

[19] If carbon reduction goals are implemented under the Kyoto Protocol, however, the economics of a natural gas pipeline from mainland Asia, as has been discussed in recent years, could become more favorable.

Hydropower, which has played a role in moderating carbon intensities in various countries, faces limited prospects for the future. Most of the best available sites in the industrialized countries have long since been exploited, and hydropower is no longer viewed as an environmentally benign energy source. New restrictions on facility relicensing could lead to decrements in hydroelectric generating capacity. The renewable energy sources of the future are most likely to be wind, solar (especially solar photovoltaics), and closed-loop biomass.[20] Although the use of these non-carbon-producing energy sources has increased only slightly in recent years, binding limits on carbon emissions such as those specified in the Kyoto Protocol could greatly enhance their economic prospects.

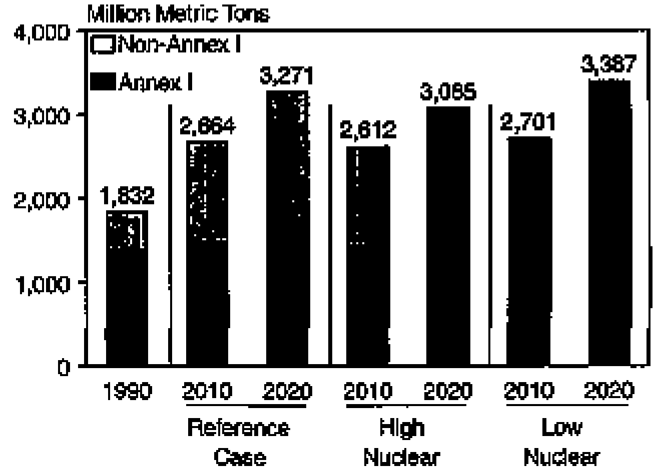
Nuclear Power and Carbon Emissions

In addition to the reference case, *IEO99* includes low and high capacity cases for nuclear power—an energy source that does not emit any greenhouse gases. The projected impacts of the different nuclear capacity cases on worldwide carbon emissions can be seen if it is assumed that world electricity demand, and the amount of energy needed to generate electricity, does not vary across the reference, high nuclear, and low nuclear cases. The resulting projections of fossil fuel consumption and carbon emissions in the three cases show the effects of the higher and lower nuclear capacity assumptions.

In the high nuclear case, projected worldwide nuclear generation of electricity is higher than the reference case projection by 5 percent in 2010 and 29 percent in 2020. In the reference case, fossil fuels provide 124 quadrillion Btu of energy for electricity generation in 2010 (65 percent of the total 191 quadrillion Btu used to produce electricity) and 156 quadrillion Btu in 2020 (68 percent of the total 227 quadrillion Btu). In the high nuclear case, fossil energy consumption for electricity generation in 2020 would be reduced by only 6.4 quadrillion Btu. Accordingly, worldwide carbon emissions from electricity generation would be reduced by only 52 million metric tons in 2010 and 206 million metric tons in 2020 in the high nuclear case from the reference case projections of 2,664 and 3,271 million metric tons, respectively (Figure 97).

Assuming that the increase in nuclear generation would displace coal, which is the most carbon-intense of the fossil fuels, a 206 million metric ton reduction would represent an upper bound for the carbon reduction in the high nuclear case. Alternatively, if nuclear generation displaced natural gas, carbon emissions would be reduced by about 115 million metric tons in the high nuclear case in 2020 relative to the reference case projection.

Figure 97. Carbon Emissions From Electricity Generation in Three Cases, 1990, 2010, and 2020



Note: The high nuclear case assumes that nuclear generation replaces coal-fired generation. The low nuclear case assumes that gas-fired generation replaces nuclear generation.

Sources: **1990:** Derived from Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

In the low nuclear case, projected carbon emissions are higher than in the reference case. Nuclear electricity generation worldwide would be reduced by 10 percent in 2010 and by nearly 37 percent in 2020—representing losses of 2.6 and 8.0 quadrillion Btu of nuclear power, respectively. It is technically possible that renewable energy sources could be substituted for the lost nuclear generation with no relative increase in carbon emissions; however, this would require an 88-percent increase in worldwide consumption of renewable energy sources between 1996 and 2020, as compared with the projected increase of 62 percent in the reference case. If natural gas were used instead, carbon emissions from electricity generation would be 38 million metric tons higher in 2010 and 116 million metric tons higher in 2020 than in the reference case (Figure 97).

Natural gas is considered the most likely substitute for the lost nuclear capacity because it is the cleanest of the fossil fuels and would minimize the impact on carbon emissions. If coal were substituted for the lost nuclear generation, an additional 204 million metric tons of carbon would be emitted in 2020—88 million metric tons more than would be emitted if gas were used.

[20] "Closed-loop" biomass electricity generation uses wood grown specifically for use as a boiler fuel, and the carbon released during its burning is considered to have been previously sequestered, with no net release to the environment. In contrast, wood from existing forests would not be considered closed-loop biomass if its harvesting led to a net deforestation.

Historical and Projected Carbon Emissions

Despite projections of decreasing energy intensities and relatively stable carbon intensities, total carbon emissions from the industrialized nations are projected to grow (Figure 98), with GDP growth rates exceeding the rates of reduction in energy intensity. Growth is expected to be particularly strong in North America, where relatively robust economic growth and flat carbon intensity more than offset reductions in energy intensity. Carbon emissions are projected to increase in North America by about 47 percent in the 30-year period between 1990 and 2020. Smaller increases are projected for Western Europe and industrialized Asia—19 percent and 32 percent, respectively. For the industrialized nations as a group, GDP growth is expected to be the most significant factor underlying the increase in carbon emissions (Figure 99).

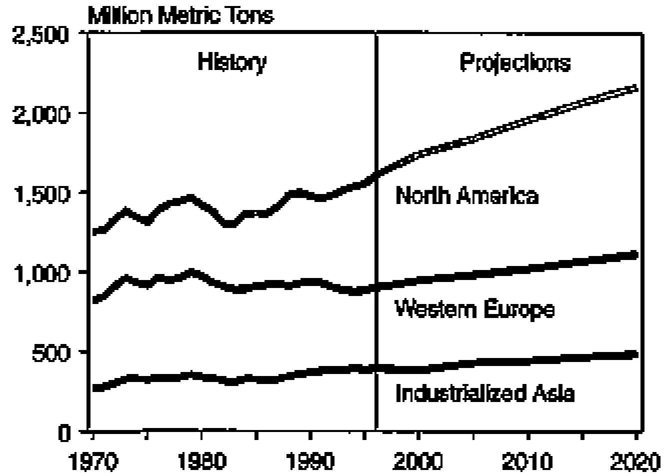
Analysis of Kyoto Protocol Impacts on the U.S. Economy

For the United States, the National Energy Modeling System (NEMS) has been used to analyze the impacts of the Kyoto Protocol [2]. In order to address the uncertainties of international carbon mitigation activities, offsets from other greenhouse gases, and carbon-absorbing sinks, several scenarios with different targets for energy-related carbon emissions were represented (Table 21). In the most stringent case, where all emissions reductions would be accomplished domestically, the Kyoto target reduction would be 7 percent below the 1990 level (1990-7%), reaching 1,243 million metric tons of carbon in 2010—548 million metric tons or 31 percent below the baseline projection of 1,791 million metric tons in 2010.[21] Total U.S. energy consumption in the 1990-7% case would be reduced by 17.5 percent from the reference case. Almost half the carbon reduction would be accounted for by changes in carbon intensity and about 40 percent by changes in energy intensity.

To achieve such reductions, a carbon price would be applied to the cost of energy produced from each energy fuel according to its carbon content. The cost of all energy would rise, but the cost of energy produced from high-carbon sources would rise the most. It is assumed that the government would competitively auction permits and recycle the revenue to citizens. The cost to the economy would not be in the permits *per se* but in the adjustment to the price of energy relative to other inputs such as capital and labor. This price represents the marginal cost of achieving the specified reduction. In the most stringent case the carbon price in 2010 is estimated to peak at $348 per metric ton (in 1996 dollars), causing retail energy prices to increase relative to the reference case by 53 percent for gasoline, 86 percent for electricity, and 110 percent for residential natural gas.

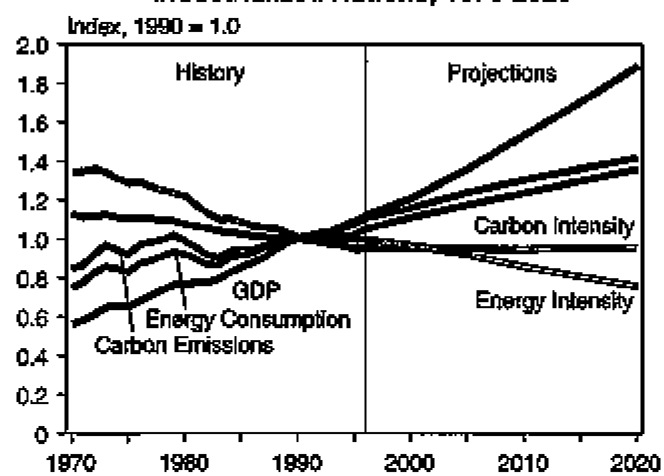
Of the fossil fuels, coal use and related emissions would decline the most in the 1990-7% carbon reduction case and continue to fall (Figure 100). Petroleum use would

Figure 98. Energy-Related Carbon Emissions in Industrialized Countries by Region, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

Figure 99. Changes in Key Factors Affecting Energy-Related Carbon Emissions in Industrialized Nations, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

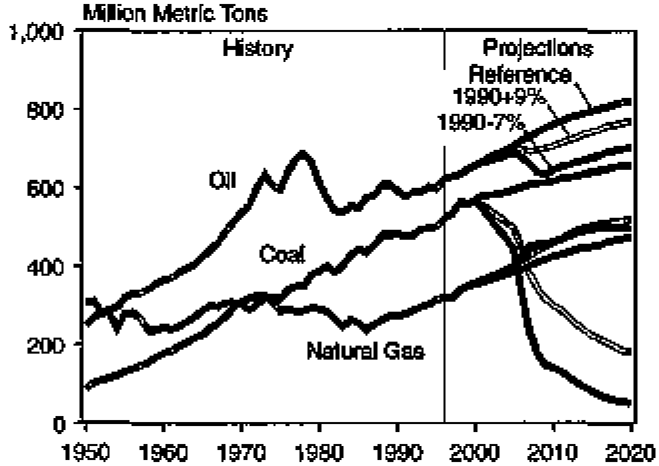
[21] This section of the chapter focuses on 2010, which is the middle of the commitment period for the Kyoto Protocol. Because the report was published in October 1998, the analysis was performed relative to the *Annual Energy Outlook 1998* reference case projections, which were the most recent available.

Table 21. Effects of Kyoto Protocol Analysis Cases on U.S. Energy Intensity and Carbon Intensity, 2010

Kyoto Protocol Analysis Case	Total Carbon Emissions in 2010 (Million Metric Tons)	Change From Reference Case (Million Metric Tons)	Energy Intensity (Quadrillion Btu per 1997 Dollar GDP)	Carbon Intensity (Million Metric Tons per Quadrillion Btu)
Reference Case	1,791	—	10.57	16.11
1990+24%	1,668	-123	10.23	15.66
1990-7%	1,243	-548	9.10	13.56

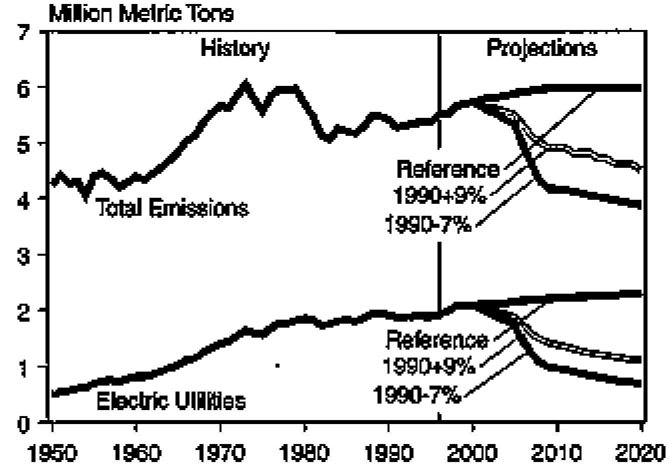
Source: Energy Information Administration, *Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity*, DOE/EIA-SR/OIAF/98-03 (Washington, DC, October 1998).

Figure 100. U.S. Energy-Related Carbon Emissions by Fuel in Three Cases, 1950-2020



Sources: **History:** Energy Information Administration (EIA), *Emissions of Greenhouse Gases in the United States 1997*, DOE/EIA-0573(97) (Washington, DC, October 1998). **Projections:** EIA, *Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity*, SR/OIAF/98-03 (Washington, DC, October 1998).

Figure 101. U.S. Carbon Emissions per Capita in Three Cases, 1950-2020



Sources: **History:** Energy Information Administration (EIA), *Emissions of Greenhouse Gases in the United States 1997*, DOE/EIA-0573(97) (Washington, DC, October 1998). **Projections:** EIA, *Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity*, SR/OIAF/98-03 (Washington, DC, October 1998).

drop initially but recover somewhat over time. Natural gas use would increase and stay above the baseline, raising the emissions attributable to natural gas above the baseline projection. Overall, carbon emissions per capita would return to a level last seen in the United States in about 1950 [6] (Figure 101).

Other, less stringent cases in the analysis measured a range of possible reductions between the most stringent case and the reference or baseline case. Those cases were based on various assumptions about levels of international permit trading, credits for carbon sinks, and offsets from other greenhouse gases. In the case with the least stringent target (1990+24%), U.S. carbon emissions would be reduced by 123 million metric tons from the baseline. In a mid-range case (1990+9%), emissions would be reduced by 329 million metric tons. The emissions targets in these two scenarios would be 425 million metric tons and 219 million metric tons higher, respectively, than the target of 1,243 million metric tons that is achieved in the 1990-7% case.[22] In these cases, the cost of energy and the impacts on the U.S. economy would be substantially less than in the most stringent carbon reduction case.

The additional reductions needed to meet the Kyoto target could be acquired in the form of carbon credits or emissions permits projected to be available for purchase from the transitional Annex I countries. If, as projected, 374 million metric tons were available on the international permit market, there would still be 155 million metric tons available for other countries after the United States had acquired the amount required to meet its goal. If, however, the United States needed to acquire permits for 415 million metric tons, an additional 41 million metric tons (above the 374 available from transitional Annex I countries) would have to be obtained by additional trading of permits and the "clean

[22]Since the Kyoto Protocol analysis was published, there have been slight changes in the U.S. baseline that affect the calculation of the Kyoto goal.

development mechanism"[23] in partnership with developing countries, as well as carbon sinks and offsets from other greenhouse gases.

The potential impacts on economic growth in the various Kyoto Protocol analysis cases are an important consideration. Even in the most stringent case, 1990-7%, GDP is projected to continue growing between 1996 and 2010, but the projected increase is less than the increase expected in the reference case. Two factors were considered in evaluating the impacts of carbon reduction efforts on economic growth: (1) loss in potential GDP and (2) macroeconomic adjustment cost.

The loss in potential GDP is a measure of the opportunities that would be forgone in the process of reconfiguring the inputs to the economy (capital, labor, energy, and materials) to a new set of relative prices. The EIA analysis estimated the loss in potential U.S. GDP to be from $13 billion to $72 billion (1992 dollars) in 2010, or between 0.1 percent and 0.8 percent of the total.

Because the adjustment to the economy would not happen instantly, there would also be a transition or macroeconomic adjustment cost that would reduce actual GDP. For example, workers in industries that produce high levels of carbon emissions might be laid off, potentially either becoming unemployed or taking lower-paying jobs during the transition period. As a result, actual GDP would decrease.

The macroeconomic adjustment period and resulting costs could be greatly affected by government policy. The EIA analysis assumed the introduction of a carbon permit trading system, in the form of an auction run by the Federal Government (to focus on the most economically efficient means of reducing carbon emissions). It was assumed that revenues from the permit auction would be recycled to the economy and would, as a result, counteract the adverse short-term effects of higher energy prices. Revenue recycling in a way that encouraged greater investment—for example, through a reduction in social security taxes—would be more effective in reducing the transition costs than would a revenue recycling approach that provided less stimulus for investment, such as a reduction in personal income taxes. Greater investment would allow the necessary adjustments to be made more rapidly.

The EIA analysis estimated that, with revenues recycled through social security taxes, actual GDP losses would range from $96 billion (in the 1990+24% case) to $397 billion (in the 1990-7% case), in the context of an economy that totaled $6,928 billion (1992 dollars) in 1996 and was projected to increase to $9,429 billion in 2010 in the reference case.

Emissions Reductions in Western Europe and Industrialized Asia

If Western Europe and industrialized Asia are to achieve Kyoto target reductions without permit trading or other offsets, they will have to make similar changes in either energy intensity or carbon intensity (or a combination of both). For Western Europe to achieve all its emissions reduction (160 million metric tons) through a reduction in carbon intensity would require a decrease from 13.69 to 11.56 million metric tons per quadrillion Btu, or about 16 percent below the projected baseline. This would be a difficult goal to achieve. Using a simple calculation for achieving the necessary reduction in emissions, electricity generation from nonfossil fuels would have to increase by 12 percent above the baseline, oil demand would have to decrease by 50 percent below the baseline, coal use would have to be eliminated, and natural gas use would have to increase by 102 percent above the baseline, all within about a decade's time.

If Western Europe achieved its reduction target solely on the basis of cuts in energy intensity, then the resulting ratio would be 5.39 rather than 6.39 thousand Btu per dollar of GDP or again about 16 percent below the projected baseline. This would mean total energy demand of about 63 quadrillion Btu in 2010 as opposed to a baseline of about 75. Such a decline would require a decrease in energy intensity of 27 percent between 2000 and 2010, which would be considerably greater than the 15 percent decline recorded between 1980 and 1990.

For industrialized Asia, if energy intensity were held constant, carbon intensity would have to decline from 14.08 to 11.49 million metric tons of carbon per quadrillion Btu to achieve the Kyoto goal (a reduction of 81 million metric tons). If carbon intensity were held constant, energy intensity would have to drop to 4.54 thousand Btu per dollar of GDP (18 percent below the baseline), reducing total demand by 25 quadrillion Btu, to approximately the 1994 level of energy demand.

Because both regions have relatively low energy intensities, it is likely that targeted reductions would be achieved through changes in carbon intensities rather than energy intensities. Industrialized Asia may have a particularly difficult time reaching the Kyoto goal. The region already has achieved below-average energy intensity, and because of logistics and economics, reducing carbon intensity through greater use of natural gas may be difficult. Emissions trading may be the key to achieving reductions with minimal adverse economic impacts [7].

[23]The clean development mechanism (CDM) would allow an Annex I country to purchase a reduction from a non-Annex I country by providing funds for a project that would not otherwise be undertaken and would lead to lower net carbon emissions in that country. Full details on the rules of CDM agreements await further negotiation.

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6. Energy Information Administration, *Emissions of Greenhouse Gases in the United States 1997*, DOE/EIA-0573(97) (Washington, DC, October 1998).

7. A. Decaux and D. Ellerman, "Analysis of Post-Kyoto Emissions Trading Using Marginal Abatement Curves," presented to the Electric Utilities Environmental Conference (Tucson, AZ, January 11-13, 1999).

Appendix A

Reference Case Projections:

- World Energy Consumption
- Gross Domestic Product
- Carbon Emissions
- Nuclear Power Capacity
- World Population

Table A1. World Total Energy Consumption by Region, Reference Case, 1990-2020
(Quadrillion Btu)

Region/Country	History			Projections					Average Annual Percent Change, 1996-2020
	1990	1995	1996	2000	2005	2010	2015	2020	
Industrialized Countries									
North America	**99.7**	**108.0**	**111.6**	**119.3**	**126.9**	**134.9**	**141.3**	**147.5**	**1.2**
United States[a]	83.9	90.4	93.3	99.2	104.7	110.8	115.5	119.9	1.0
Canada	10.9	12.2	12.6	13.5	14.5	15.4	16.2	16.9	1.2
Mexico	4.9	5.5	5.6	6.5	7.7	8.6	9.6	10.7	2.7
Western Europe	**60.0**	**62.3**	**64.0**	**67.6**	**71.3**	**74.6**	**77.9**	**81.5**	**1.0**
United Kingdom	9.4	9.3	9.9	10.5	11.2	11.7	12.3	12.8	1.1
France	9.3	10.2	10.6	11.0	11.5	12.0	12.5	13.0	0.9
Germany	14.7	14.2	14.5	15.2	16.0	16.8	17.6	18.4	1.0
Italy	6.7	7.1	7.2	7.6	8.1	8.6	9.1	9.6	1.2
Netherlands	3.3	3.5	3.7	3.9	4.1	4.4	4.6	4.8	1.1
Other Western Europe	16.6	18.0	18.2	19.4	20.3	21.1	21.9	22.8	1.0
Industrialized Asia	**23.0**	**26.3**	**26.9**	**26.3**	**29.6**	**30.9**	**32.4**	**33.9**	**1.0**
Japan	18.1	20.8	21.4	20.4	23.3	24.4	25.6	26.7	0.9
Australasia	4.9	5.6	5.5	5.9	6.2	6.5	6.8	7.1	1.1
Total Industrialized	**182.7**	**196.6**	**202.5**	**213.2**	**227.8**	**240.4**	**251.6**	**262.8**	**1.1**
EE/FSU									
Former Soviet Union	58.5	40.8	39.8	38.4	41.8	44.7	47.8	51.1	1.0
Eastern Europe	15.2	12.4	12.6	13.5	15.1	16.3	17.5	18.7	1.7
Total EE/FSU	**73.8**	**53.2**	**52.4**	**52.0**	**56.9**	**61.0**	**65.3**	**69.8**	**1.2**
Developing Countries									
Developing Asia	**51.4**	**71.8**	**74.5**	**84.5**	**106.1**	**127.6**	**151.0**	**177.9**	**3.7**
China	27.0	36.4	37.1	43.6	55.0	67.6	81.8	98.3	4.1
India	7.7	11.1	11.6	14.1	17.5	20.8	24.2	28.2	3.8
South Korea	3.7	6.5	7.2	7.5	9.4	11.3	13.3	15.4	3.2
Other Asia	13.0	17.8	18.8	19.3	24.1	28.0	31.8	36.0	2.8
Middle East	**13.1**	**16.4**	**17.3**	**20.1**	**23.5**	**27.0**	**30.8**	**34.7**	**2.9**
Turkey	2.0	2.5	2.7	3.2	3.7	4.2	4.8	5.5	3.0
Africa	**9.2**	**10.7**	**11.1**	**12.0**	**13.8**	**15.5**	**17.1**	**18.9**	**2.3**
Central and South America	**13.7**	**16.8**	**17.7**	**21.0**	**26.3**	**32.6**	**39.4**	**47.7**	**4.2**
Brazil	5.4	6.4	6.8	7.1	8.7	10.6	12.7	15.2	3.4
Other Central/South America	8.3	10.4	10.9	13.9	17.7	22.0	26.7	32.4	4.7
Total Developing	**87.4**	**115.7**	**120.6**	**137.6**	**169.6**	**202.8**	**238.2**	**279.2**	**3.6**
Total World	**343.8**	**365.6**	**375.5**	**402.7**	**454.3**	**504.2**	**555.1**	**611.8**	**2.1**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Energy totals include net imports of coal coke and electricity generated from biomass in the United States. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table A1; and World Energy Projection System (1999).

Table A2. World Total Energy Consumption by Region and Fuel, Reference Case, 1990-2020
(Quadrillion Btu)

Region/Country	History			Projections					Average Annual Percent Change, 1996-2020
	1990	1995	1996	2000	2005	2010	2015	2020	
Industrialized Countries									
North America									
Oil	40.4	41.8	43.2	47.0	49.8	53.5	56.3	59.1	1.3
Natural Gas	22.7	26.2	26.8	28.2	31.8	35.1	38.4	40.5	1.7
Coal	20.4	21.1	22.0	24.3	24.9	25.7	26.8	28.1	1.0
Nuclear	7.0	8.3	8.2	8.0	7.6	6.8	5.4	4.5	-2.5
Other	9.2	10.6	11.4	11.7	12.9	13.8	14.4	15.2	1.2
Total	**99.7**	**108.0**	**111.6**	**119.3**	**126.9**	**134.9**	**141.3**	**147.5**	**1.2**
Western Europe									
Oil	25.8	26.0	28.2	29.8	30.6	31.5	32.2	33.0	0.7
Natural Gas	9.9	12.2	13.7	15.7	18.4	20.8	23.8	27.1	2.9
Coal	12.5	9.1	9.1	8.4	7.8	7.3	6.9	6.4	-1.4
Nuclear	7.4	8.2	8.6	8.9	8.9	8.6	8.0	7.3	-0.7
Other	4.4	4.8	4.5	4.8	5.7	6.3	7.0	7.8	2.2
Total	**60.0**	**62.3**	**64.0**	**67.6**	**71.3**	**74.6**	**77.9**	**81.5**	**1.0**
Industrialized Asia									
Oil	12.5	14.1	14.3	13.9	14.4	15.2	15.9	16.7	0.7
Natural Gas	2.9	3.3	3.6	3.4	5.1	4.9	5.5	6.0	2.2
Coal	4.2	4.6	4.7	4.6	5.2	5.3	5.3	5.4	0.6
Nuclear	2.0	2.8	2.9	3.1	3.1	3.8	3.7	3.7	1.0
Other	1.4	1.4	1.4	1.3	1.8	1.8	1.9	2.0	1.6
Total	**23.0**	**26.3**	**26.9**	**26.3**	**29.6**	**30.9**	**32.4**	**33.9**	**1.0**
Total Industrialized									
Oil	78.7	83.9	85.7	90.7	94.7	100.2	104.5	108.9	1.0
Natural Gas	35.5	41.8	44.0	47.4	55.3	60.8	67.7	73.7	2.2
Coal	37.2	34.8	35.8	37.3	37.8	38.3	39.1	40.0	0.5
Nuclear	16.3	19.4	19.8	20.0	19.6	19.2	17.0	15.5	-1.0
Other	15.0	16.8	17.2	17.8	20.3	21.9	23.3	24.8	1.5
Total	**182.7**	**196.6**	**202.5**	**213.1**	**227.8**	**240.4**	**251.6**	**262.8**	**1.1**
EE/FSU									
Oil	21.0	12.4	12.0	12.5	12.7	13.4	13.9	14.4	0.8
Natural Gas	26.0	21.4	21.7	22.2	26.4	30.2	34.0	38.7	2.4
Coal	20.8	13.8	13.0	11.8	11.8	11.1	10.2	9.1	-1.5
Nuclear	2.9	2.5	2.6	2.8	2.9	3.0	3.1	2.7	-0.2
Other	2.8	3.0	2.9	2.7	3.1	3.4	4.1	4.9	2.3
Total	**73.6**	**53.2**	**52.4**	**52.0**	**56.9**	**61.0**	**65.3**	**69.8**	**1.2**
Developing Countries									
Developing Asia									
Oil	16.0	23.6	24.8	28.4	32.4	38.7	45.5	50.9	3.0
Natural Gas	3.0	5.1	5.7	6.8	13.1	18.1	24.8	31.9	7.4
Coal	26.1	38.0	38.7	43.0	51.5	60.3	68.9	82.4	3.2
Nuclear	0.9	1.2	1.3	1.5	2.1	2.6	3.0	3.2	3.8
Other	3.2	4.0	4.0	4.8	7.0	7.8	8.7	9.6	3.7
Total	**51.4**	**71.8**	**74.5**	**84.5**	**106.1**	**127.6**	**151.0**	**177.9**	**3.7**

See notes at end of table.

Table A2. World Total Energy Consumption by Region and Fuel, Reference Case, 1990-2020 (Continued)
(Quadrillion Btu)

Region/Country	History			Projections					Average Annual Percent Change, 1996-2020
	1990	1995	1996	2000	2005	2010	2015	2020	
Developing Countries (Continued)									
Middle East									
Oil	8.1	9.8	10.1	10.9	13.7	15.7	17.9	20.6	3.0
Natural Gas	3.9	5.2	5.7	7.3	7.8	9.0	10.2	11.4	2.9
Coal	0.8	0.8	0.9	1.0	1.0	1.1	1.1	1.1	1.1
Nuclear	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.2	--
Other	0.4	0.5	0.6	0.9	1.0	1.1	1.3	1.5	4.0
Total	**13.1**	**16.4**	**17.3**	**20.1**	**23.5**	**27.0**	**30.6**	**34.7**	**2.9**
Africa									
Oil	4.2	4.6	5.0	5.5	6.2	7.3	8.4	9.7	2.8
Natural Gas	1.4	1.9	2.0	2.1	2.7	3.1	3.4	3.7	2.7
Coal	3.0	3.3	3.4	3.5	3.8	4.0	4.1	4.3	1.0
Nuclear	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	-0.2
Other	0.6	0.6	0.6	0.7	0.9	1.0	1.1	1.2	2.8
Total	**9.2**	**10.7**	**11.1**	**12.0**	**13.8**	**15.5**	**17.1**	**18.9**	**2.3**
Central and South America									
Oil	6.9	8.0	8.1	9.7	12.9	15.1	17.4	20.3	3.9
Natural Gas	2.1	2.9	3.1	4.3	6.0	9.6	13.5	18.1	7.6
Coal	0.7	0.8	1.0	1.1	1.2	1.2	1.3	1.4	1.4
Nuclear	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.1	1.3
Other	3.9	5.1	5.4	5.8	6.1	6.5	7.1	7.7	1.5
Total	**13.7**	**16.8**	**17.7**	**21.0**	**26.3**	**32.6**	**39.4**	**47.7**	**4.2**
Total Developing Countries									
Oil	35.2	46.2	48.1	54.5	65.2	76.6	89.2	101.3	3.2
Natural Gas	10.5	15.0	16.5	20.5	29.6	39.8	51.9	65.1	5.9
Coal	32.5	42.9	43.9	48.7	57.5	66.6	75.5	89.2	3.0
Nuclear	1.1	1.4	1.5	1.7	2.4	3.0	3.5	3.6	3.6
Other	8.1	10.2	10.6	12.2	14.9	16.5	18.2	20.0	2.7
Total	**87.4**	**115.7**	**120.6**	**137.8**	**169.6**	**202.6**	**238.2**	**279.2**	**3.6**
Total World									
Oil	134.9	142.5	145.7	157.7	172.7	190.4	207.5	224.6	1.8
Natural Gas	72.0	78.1	82.2	90.1	111.3	130.8	153.6	177.5	3.3
Coal	90.6	91.6	92.8	97.7	107.1	116.0	124.8	136.3	1.7
Nuclear	20.4	23.3	24.1	24.5	24.9	25.2	23.6	21.7	-0.4
Other	25.9	30.1	30.7	32.7	38.3	41.9	45.6	49.7	2.0
Total	**343.8**	**365.6**	**375.5**	**402.7**	**454.3**	**504.2**	**555.1**	**611.8**	**2.1**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Energy totals include net imports of coal coke and electricity generated from biomass in the United States. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table A1; and World Energy Projection System (1999).

Table A3. World Gross Domestic Product (GDP) by Region, Reference Case, 1990-2020
(Billion 1997 Dollars)

Region/Country	History			Projections					Percent Change, 1996-2020	
	1990	1995	1996	2000	2005	2010	2015	2020	Annual Average	Total
Industrialized Countries										
North America	**7,726**	**8,492**	**8,776**	**9,860**	**11,133**	**12,645**	**13,918**	**15,210**	**2.3**	**73.3**
United States[a]	6,848	7,546	7,806	8,736	9,788	11,044	12,055	13,035	2.2	67.0
Canada	546	588	596	671	775	884	977	1,079	2.5	81.2
Mexico	332	358	377	454	570	717	887	1,098	4.6	191.0
Western Europe	**7,565**	**8,116**	**8,258**	**9,136**	**10,371**	**11,679**	**13,108**	**14,713**	**2.4**	**78.2**
United Kingdom	1,143	1,219	1,246	1,372	1,582	1,786	2,006	2,252	2.5	80.8
France	1,269	1,340	1,361	1,496	1,669	1,867	2,072	2,298	2.2	68.9
Germany	1,839	2,019	2,045	2,242	2,564	2,902	3,276	3,698	2.5	80.8
Italy	1,060	1,121	1,128	1,228	1,396	1,571	1,764	1,980	2.4	75.5
Netherlands	303	336	347	394	446	500	561	628	2.5	81.3
Other Western Europe	1,951	2,083	2,132	2,402	2,715	3,052	3,430	3,857	2.5	80.9
Industrialized Asia	**4,094**	**4,424**	**4,602**	**4,388**	**4,910**	**5,553**	**6,265**	**7,068**	**1.8**	**53.6**
Japan	3,720	3,994	4,158	3,896	4,358	4,938	5,576	6,297	1.7	51.5
Australasia	374	429	444	491	552	615	689	771	2.3	73.6
Total Industrialized	**19,384**	**21,034**	**21,638**	**23,384**	**26,414**	**29,877**	**33,291**	**36,992**	**2.3**	**71.0**
EE/FSU										
Former Soviet Union	1,049	621	594	549	645	749	871	1,013	2.3	70.7
Eastern Europe	356	333	347	410	526	647	771	920	4.1	165.2
Total EE/FSU	**1,404**	**954**	**940**	**959**	**1,171**	**1,396**	**1,642**	**1,933**	**3.0**	**105.6**
Developing Countries										
Developing Asia	**1,726**	**2,536**	**2,727**	**3,076**	**4,168**	**5,510**	**7,147**	**9,285**	**5.2**	**240.5**
China	440	777	851	1,069	1,532	2,115	2,867	3,886	6.5	356.5
India	278	345	370	452	583	750	961	1,230	5.1	232.7
South Korea	273	392	419	435	590	782	1,016	1,320	4.9	214.6
Other Asia	734	1,023	1,087	1,121	1,462	1,863	2,304	2,849	4.1	162.2
Middle East	**378**	**460**	**487**	**539**	**670**	**831**	**1,017**	**1,245**	**4.0**	**155.6**
Turkey	143	167	179	216	266	328	406	503	4.4	180.8
Africa	**244**	**258**	**267**	**290**	**358**	**436**	**521**	**623**	**3.6**	**133.1**
Central and South America	**1,116**	**1,349**	**1,392**	**1,516**	**1,950**	**2,483**	**3,095**	**3,859**	**4.3**	**177.2**
Brazil	660	756	778	808	1,016	1,274	1,572	1,940	3.9	149.4
Other Central/South America	457	593	614	709	934	1,209	1,523	1,919	4.9	212.5
Total Developing	**3,465**	**4,603**	**4,873**	**5,422**	**7,145**	**9,260**	**11,780**	**15,012**	**4.8**	**208.0**
Total World	**24,253**	**26,592**	**27,452**	**29,765**	**34,730**	**40,533**	**46,713**	**53,936**	**2.9**	**96.5**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding.

Sources: **History:** The WEFA Group, *World Economic Outlook: 20-Year Extension* (Eddystone, PA, April 1997). **Projections:** Standard & Poor's DRI, *World Economic Outlook*, Vol. 1 (Lexington, MA, 3rd Quarter 1998); Energy Information Administration (EIA), *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table A20; and EIA, World Energy Projection System (1999).

Table A4. World Oil Consumption by Region, Reference Case, 1990-2020
(Million Barrels per Day)

Region/Country	History			Projections					Average Annual Percent Change, 1996-2020
	1990	1995	1996	2000	2005	2010	2015	2020	
Industrialized Countries									
North America	20.4	21.3	22.0	23.6	25.5	27.4	28.8	30.2	1.3
United States[a]	17.0	17.7	18.3	19.5	21.2	22.7	23.7	24.7	1.2
Canada	1.7	1.8	1.8	2.0	2.0	2.1	2.2	2.3	1.0
Mexico	1.7	1.9	1.9	2.0	2.3	2.6	2.9	3.3	2.4
Western Europe	12.5	13.5	13.7	14.4	14.8	15.3	15.6	16.0	0.7
United Kingdom	1.8	1.8	1.8	1.9	2.0	2.1	2.1	2.2	0.7
France	1.8	1.9	1.9	2.0	2.1	2.1	2.2	2.2	0.6
Germany	2.7	2.9	2.9	3.0	3.1	3.2	3.3	3.3	0.6
Italy	1.9	2.0	2.1	2.1	2.3	2.5	2.6	2.8	1.2
Netherlands	0.7	0.8	0.8	0.8	0.9	0.9	0.9	0.9	0.6
Other Western Europe	3.6	4.1	4.1	4.7	4.4	4.5	4.5	4.6	0.4
Industrialized Asia	6.2	7.0	7.1	6.8	7.1	7.5	7.9	8.3	0.7
Japan	5.1	5.7	5.9	5.6	5.7	6.0	6.3	6.6	0.5
Australasia	1.0	1.2	1.2	1.2	1.4	1.5	1.6	1.7	1.4
Total Industrialized	39.0	41.8	42.7	44.9	47.4	50.1	52.3	54.5	1.0
EE/FSU									
Former Soviet Union	8.4	4.6	4.4	4.4	4.5	4.7	4.9	5.2	0.7
Eastern Europe	1.6	1.3	1.3	1.6	1.6	1.7	1.7	1.7	1.0
Total EE/FSU	10.0	5.9	5.7	6.0	6.1	6.4	6.6	6.9	0.8
Developing Countries									
Developing Asia	7.6	11.3	11.9	13.6	15.5	18.5	21.6	24.3	3.0
China	2.3	3.3	3.5	4.6	5.0	6.4	8.1	8.8	3.8
India	1.2	1.6	1.7	1.9	2.6	3.1	3.5	4.1	3.6
South Korea	1.0	2.0	2.2	2.1	2.8	3.4	4.0	4.7	3.3
Other Asia	3.1	4.3	4.5	5.0	5.1	5.7	6.3	6.8	1.6
Middle East	3.9	4.7	4.8	5.2	6.5	7.5	8.5	9.8	3.0
Turkey	0.5	0.6	0.6	0.7	0.9	1.0	1.2	1.4	3.2
Africa	2.1	2.3	2.4	2.7	3.0	3.5	4.1	4.7	2.8
Central and South America	3.4	3.9	4.0	4.8	6.3	7.4	8.5	10.0	3.9
Brazil	1.3	1.5	1.5	1.6	1.9	2.3	2.8	3.4	3.4
Other Central/South America	2.1	2.4	2.5	3.2	4.5	5.1	5.8	6.6	4.2
Total Developing	17.0	22.2	23.1	26.2	31.4	37.0	42.9	48.7	3.2
Total World	66.0	69.9	71.5	77.1	84.8	93.5	101.8	110.1	1.8

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table A21; and World Energy Projection System (1999).

Table A5. World Natural Gas Consumption by Region, Reference Case, 1990-2020
(Trillion Cubic Feet)

Region/Country	History			Projections					Average Annual Percent Change, 1996-2020
	1990	1995	1996	2000	2005	2010	2015	2020	
Industrialized Countries									
North America	**22.0**	**25.4**	**26.0**	**27.4**	**30.8**	**34.0**	**37.3**	**39.3**	**1.7**
United States[a]	18.7	21.6	21.9	22.5	25.2	28.0	30.8	32.3	1.6
Canada	2.4	2.9	3.1	3.3	3.6	3.8	4.1	4.5	1.7
Mexico	0.9	1.0	1.0	1.5	2.0	2.1	2.3	2.5	3.8
Western Europe	**10.1**	**12.4**	**13.8**	**15.6**	**18.5**	**20.9**	**23.8**	**27.1**	**2.9**
United Kingdom	2.1	2.7	3.2	3.9	4.5	5.0	5.5	6.1	2.8
France	1.0	1.2	1.3	1.5	1.8	2.1	2.4	3.0	3.4
Germany	2.7	3.4	3.7	4.2	4.9	5.7	6.7	7.5	3.0
Italy	1.7	1.9	2.0	2.2	2.3	2.4	2.6	2.8	1.4
Netherlands	1.5	1.7	1.9	2.1	2.2	2.3	2.4	2.6	1.4
Other Western Europe	1.2	1.6	1.8	1.9	2.9	3.4	4.3	5.2	4.6
Industrialized Asia	**2.6**	**3.1**	**3.3**	**3.2**	**4.7**	**4.5**	**5.1**	**5.5**	**2.2**
Japan	1.9	2.2	2.4	2.1	3.6	3.4	3.9	4.4	2.5
Australasia	0.8	0.9	0.9	1.1	1.1	1.1	1.1	1.2	1.1
Total Industrialized	**34.8**	**41.0**	**43.1**	**46.4**	**54.0**	**59.5**	**66.2**	**72.0**	**2.2**
EE/FSU									
Former Soviet Union	25.0	20.6	20.7	20.6	23.9	26.5	29.4	33.0	2.0
Eastern Europe	3.1	2.7	2.9	3.5	4.7	6.2	7.5	8.9	4.8
Total EE/FSU	**28.1**	**23.4**	**23.7**	**24.1**	**28.6**	**32.7**	**36.8**	**41.9**	**2.4**
Developing Countries									
Developing Asia	**3.0**	**4.7**	**5.3**	**6.2**	**12.0**	**16.5**	**22.6**	**28.9**	**7.3**
China	0.5	0.6	0.7	1.3	2.9	4.3	7.0	9.5	11.7
India	0.4	0.6	0.7	1.2	1.9	2.8	3.8	5.0	8.6
South Korea	0.1	0.3	0.5	0.6	0.8	1.1	1.4	1.9	6.1
Other Asia	1.9	3.2	3.5	3.0	6.4	8.3	10.2	12.4	5.4
Middle East	**3.7**	**5.0**	**5.4**	**7.0**	**7.4**	**8.6**	**9.7**	**10.9**	**2.9**
Turkey	0.1	0.2	0.3	0.6	0.6	0.7	0.9	1.1	5.9
Africa	**1.4**	**1.7**	**1.8**	**1.9**	**2.4**	**2.8**	**3.1**	**3.3**	**2.7**
Central and South America	**2.0**	**2.6**	**2.9**	**4.0**	**5.6**	**8.9**	**12.5**	**16.8**	**7.6**
Brazil	0.1	0.2	0.2	0.3	1.0	1.7	2.6	3.5	12.5
Other Central/South America	1.9	2.4	2.7	3.7	4.6	7.2	10.0	13.4	6.9
Total Developing	**10.1**	**14.0**	**15.4**	**19.1**	**27.5**	**36.8**	**47.8**	**59.9**	**5.8**
Total World	**73.0**	**78.3**	**82.2**	**89.6**	**110.1**	**129.0**	**150.9**	**173.9**	**3.2**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country. To convert cubic feet to cubic meters, divide each number in the table by 35.315.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table A13; and World Energy Projection System (1999).

Table A6. World Coal Consumption by Region, Reference Case, 1990-2020
(Million Short Tons)

Region/Country	History			Projections					Average Annual Percent Change, 1996-2020
	1990	1995	1996	2000	2005	2010	2015	2020	
Industrialized Countries									
North America	957	1,013	1,056	1,166	1,196	1,236	1,296	1,366	1.1
United States[a]	896	941	983	1,092	1,120	1,156	1,211	1,275	1.1
Canada	55	59	60	58	57	57	61	67	0.5
Mexico	7	13	14	15	19	23	24	25	2.4
Western Europe	898	607	600	563	527	504	481	451	-1.2
United Kingdom	121	79	81	63	55	46	40	28	-4.3
France	36	26	26	20	14	8	7	6	-6.1
Germany	528	298	290	277	266	259	250	241	-0.8
Italy	25	20	19	19	20	19	19	17	-0.3
Netherlands	15	15	15	15	14	14	13	12	-1.0
Other Western Europe	173	170	170	169	158	158	152	148	-0.6
Industrialized Asia	233	257	266	259	288	291	296	300	0.5
Japan	125	140	144	135	163	166	170	172	0.7
Australasia	108	117	121	124	124	125	127	128	0.2
Total Industrialized	2,088	1,876	1,922	1,988	2,011	2,031	2,072	2,117	0.4
EE/FSU									
Former Soviet Union	848	508	472	399	395	388	368	339	-1.4
Eastern Europe	523	426	413	408	412	369	330	283	-1.6
Total EE/FSU	1,372	934	885	807	807	757	697	622	-1.5
Developing Countries									
Developing Asia	1,555	2,030	2,065	2,299	2,761	3,238	3,706	4,446	3.2
China	1,124	1,488	1,500	1,682	2,069	2,489	2,876	3,540	3.6
India	242	312	321	371	416	465	498	536	2.2
South Korea	42	51	58	62	65	77	86	90	1.9
Other Asia	146	178	186	183	210	228	247	280	1.7
Middle East	66	76	80	89	92	97	102	104	1.1
Turkey	60	67	72	79	80	88	91	93	1.1
Africa	152	172	174	183	198	208	215	222	1.0
Central and South America	30	32	40	45	47	50	52	57	1.4
Brazil	17	19	27	27	30	31	34	37	1.2
Other Central/South America	13	13	13	18	17	18	19	20	1.7
Total Developing	1,803	2,310	2,360	2,616	3,098	3,592	4,075	4,829	3.0
Total World	5,263	5,120	5,167	5,412	5,916	6,381	6,846	7,568	1.6

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country. To convert short tons to metric tons, divide each number in the table by 1.102.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table A16; and World Energy Projection System (1999).

Table A7. World Nuclear Energy Consumption by Region, Reference Case, 1990-2020
(Billion Kilowatthours)

Region/Country	History			Projections					Average Annual Percent Change, 1996-2020
	1990	1995	1996	2000	2005	2010	2015	2020	
Industrialized Countries									
North America	**649**	**774**	**770**	**746**	**710**	**633**	**498**	**422**	**-2.5**
United States[a]	577	673	675	659	630	554	419	359	-2.6
Canada	69	93	88	79	72	72	72	56	-1.9
Mexico	3	8	7	8	8	8	8	8	0.3
Western Europe	**703**	**785**	**824**	**850**	**844**	**821**	**757**	**693**	**-0.7**
United Kingdom	59	77	82	82	82	80	76	70	-0.6
France	298	358	376	400	401	409	411	395	0.2
Germany	145	146	154	159	151	132	106	106	-1.5
Italy	0	0	0	0	0	0	0	0	0.0
Netherlands	3	4	4	3	3	3	0	0	-100.0
Other Western Europe	198	200	208	207	207	198	165	122	-2.2
Industrialized Asia	**192**	**277**	**283**	**299**	**305**	**368**	**363**	**358**	**1.0**
Japan	192	277	283	299	305	368	363	358	1.0
Australasia	0	0	0	0	0	0	0	0	0.0
Total Industrialized	**1,544**	**1,837**	**1,877**	**1,896**	**1,859**	**1,822**	**1,619**	**1,473**	**-1.0**
EE/FSU									
Former Soviet Union	201	172	194	195	194	202	213	182	-0.3
Eastern Europe	54	57	60	60	73	70	68	61	0.1
Total EE/FSU	**256**	**229**	**254**	**255**	**267**	**272**	**281**	**243**	**-0.2**
Developing Countries									
Developing Asia	**88**	**117**	**128**	**149**	**205**	**258**	**296**	**312**	**3.8**
China	0	12	14	13	38	69	88	112	9.2
India	6	6	7	9	14	22	33	43	7.6
South Korea	50	64	70	92	100	107	116	106	1.7
Other Asia	32	34	37	35	53	59	60	51	1.4
Middle East	**0**	**0**	**0**	**0**	**0**	**10**	**17**	**17**	**0.0**
Turkey	0	0	0	0	0	0	6	6	0.0
Africa	**8**	**11**	**12**	**11**	**11**	**11**	**11**	**11**	**-0.2**
Central and South America	**9**	**9**	**9**	**10**	**15**	**17**	**17**	**13**	**1.3**
Brazil	2	2	2	3	8	9	9	9	5.7
Other Central/South America	7	7	7	7	7	8	8	4	-2.4
Total Developing	**105**	**138**	**149**	**170**	**232**	**296**	**341**	**353**	**3.7**
Total World	**1,905**	**2,203**	**2,280**	**2,321**	**2,358**	**2,390**	**2,241**	**2,068**	**-0.4**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table A8; and World Energy Projection System (1999).

Table A8. World Consumption of Hydroelectricity and Other Renewable Energy by Region, Reference Case, 1990-2020
(Quadrillion Btu)

Region/Country	History 1990	History 1995	History 1996	Projections 2000	Projections 2005	Projections 2010	Projections 2015	Projections 2020	Average Annual Percent Change, 1996-2020
Industrialized Countries									
North America	**9.2**	**10.6**	**11.4**	**11.7**	**12.9**	**13.8**	**14.4**	**15.2**	**1.2**
United States[a]	5.8	6.8	7.3	7.3	7.5	7.8	8.2	8.6	0.7
Canada	3.1	3.4	3.6	4.0	4.8	5.2	5.4	5.7	1.9
Mexico	0.3	0.4	0.4	0.5	0.6	0.7	0.8	0.9	3.2
Western Europe	**4.4**	**4.8**	**4.5**	**4.8**	**5.7**	**6.3**	**7.0**	**7.6**	**2.2**
United Kingdom	0.1	0.1	0.0	0.1	0.2	0.3	0.4	0.5	10.1
France	0.6	0.7	0.7	0.7	0.8	0.9	1.0	1.0	1.8
Germany	0.2	0.2	0.2	0.3	0.5	0.6	0.8	0.9	6.3
Italy	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.6	1.0
Netherlands	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	16.8
Other Western Europe	3.2	3.3	3.1	3.1	3.6	3.8	4.0	4.3	1.4
Industrialized Asia	**1.4**	**1.4**	**1.4**	**1.3**	**1.8**	**1.8**	**1.9**	**2.0**	**1.6**
Japan	1.0	0.9	0.9	0.8	1.2	1.1	1.2	1.2	1.4
Australasia	0.4	0.5	0.5	0.6	0.6	0.6	0.7	0.8	1.9
Total Industrialized	**15.0**	**16.8**	**17.2**	**17.8**	**20.3**	**21.9**	**23.3**	**24.8**	**1.5**
EE/FSU									
Former Soviet Union	2.4	2.5	2.2	2.1	2.3	2.4	2.6	2.9	1.1
Eastern Europe	0.4	0.6	0.6	0.6	0.7	1.0	1.5	2.0	4.9
Total EE/FSU	**2.8**	**3.0**	**2.9**	**2.7**	**3.1**	**3.4**	**4.1**	**4.9**	**2.3**
Developing Countries									
Developing Asia	**3.2**	**4.0**	**4.0**	**4.8**	**7.0**	**7.9**	**8.7**	**9.6**	**3.7**
China	1.3	1.9	1.9	2.2	3.8	4.2	4.4	4.5	3.7
India	0.7	0.7	0.7	1.2	1.4	1.6	2.1	2.6	5.3
South Korea	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	6.2
Other Asia	1.1	1.3	1.3	1.3	1.7	1.9	2.1	2.3	2.2
Middle East	**0.4**	**0.6**	**0.6**	**0.9**	**1.0**	**1.1**	**1.3**	**1.5**	**4.0**
Turkey	0.2	0.4	0.4	0.5	0.5	0.5	0.6	0.6	1.6
Africa	**0.6**	**0.6**	**0.6**	**0.7**	**0.9**	**1.0**	**1.1**	**1.2**	**2.8**
Central and South America	**3.9**	**5.1**	**5.4**	**5.8**	**6.1**	**6.5**	**7.1**	**7.7**	**1.5**
Brazil	2.2	2.7	2.8	2.8	3.0	3.0	3.2	3.3	0.7
Other Central/South America	1.7	2.4	2.6	2.9	3.1	3.5	3.9	4.4	2.3
Total Developing	**8.1**	**10.2**	**10.6**	**12.2**	**14.9**	**16.5**	**18.2**	**20.0**	**2.7**
Total World	**25.9**	**30.1**	**30.7**	**32.7**	**38.3**	**41.9**	**45.6**	**49.7**	**2.0**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country. U.S. totals include net electricity imports, methanol, and liquid hydrogen.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table A1; and World Energy Projection System (1999).

Table A9. World Electricity Consumption by Region, Reference Case, 1990-2020
(Billion Kilowatthours)

Region/Country	History 1990	1995	1996	Projections 2000	2005	2010	2015	2020	Average Annual Percent Change, 1996-2020
Industrialized Countries									
North America	3,255	3,759	3,859	4,004	4,329	4,671	5,028	5,359	1.4
United States[a]	2,713	3,163	3,243	3,333	3,585	3,843	4,113	4,345	1.2
Canada	435	462	473	506	536	577	616	657	1.4
Mexico	107	134	144	164	208	251	299	357	3.9
Western Europe	2,064	2,209	2,245	2,380	2,635	2,893	3,174	3,473	1.8
United Kingdom	286	301	305	318	351	381	412	445	1.6
France	324	365	378	402	440	483	527	570	1.7
Germany	485	473	473	483	539	598	662	727	1.8
Italy	222	247	248	278	320	364	413	466	2.7
Netherlands	71	82	85	94	105	117	130	144	2.2
Other Western Europe	675	742	756	804	879	950	1,030	1,121	1.7
Industrialized Asia	930	1,068	1,090	1,146	1,335	1,437	1,547	1,653	1.8
Japan	750	864	882	894	1,053	1,127	1,204	1,280	1.6
Australasia	180	204	207	251	281	310	343	373	2.5
Total Industrialized	6,248	7,037	7,194	7,529	8,298	9,001	9,749	10,485	1.6
EE/FSU									
Former Soviet Union	1,488	1,168	1,133	1,000	1,089	1,164	1,245	1,331	0.7
Eastern Europe	420	384	401	396	448	509	568	634	1.9
Total EE/FSU	1,908	1,552	1,535	1,396	1,536	1,673	1,813	1,966	1.0
Developing Countries									
Developing Asia	1,268	1,912	2,002	2,350	3,105	3,937	4,918	6,122	4.8
China	551	881	925	1,107	1,520	2,030	2,672	3,486	5.7
India	257	367	378	493	644	802	981	1,192	4.9
South Korea	95	162	181	190	237	285	335	387	3.2
Other Asia	365	501	519	560	704	819	930	1,056	3.0
Middle East	272	371	386	440	525	619	719	826	3.2
Turkey	51	76	85	128	179	262	327	452	7.2
Africa	285	320	332	371	454	544	637	746	3.4
Central and South America	449	575	604	735	950	1,182	1,421	1,728	4.5
Brazil	229	288	303	336	440	574	734	939	4.8
Other Central/South America	220	286	301	399	509	608	687	789	4.1
Total Developing	2,274	3,178	3,324	3,895	5,033	6,282	7,695	9,422	4.4
Total World	10,431	11,767	12,053	12,821	14,868	16,956	19,257	21,872	2.5

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Electricity consumption equals generation plus imports minus exports minus distribution losses.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998), Table 6.2. **Projections:** EIA, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table A8; and World Energy Projection System (1999).

Table A10. World Carbon Emissions by Region, Reference Case, 1990-2020
(Million Metric Tons)

Region/Country	History			Projections					Average Annual Percent Change, 1996-2020
	1990	1995	1996	2000	2005	2010	2015	2020	
Industrialized Countries									
North America	1,650	1,629	1,687	1,833	1,946	2,079	2,202	2,314	1.3
United States[a]	1,346	1,411	1,463	1,585	1,678	1,790	1,890	1,975	1.3
Canada	126	135	140	151	156	162	171	182	1.1
Mexico	78	82	84	97	113	127	141	158	2.7
Western Europe	936	885	904	947	983	1,021	1,066	1,114	0.9
United Kingdom	167	145	153	156	165	170	176	181	0.7
France	103	97	101	103	106	109	115	124	0.8
Germany	267	235	238	244	254	265	277	288	0.8
Italy	113	116	118	122	131	138	146	153	1.2
Netherlands	59	57	58	62	65	67	69	71	0.8
Other Western Europe	226	234	237	260	262	271	284	298	1.0
Industrialized Asia	364	379	389	377	423	435	456	479	0.9
Japan	274	281	291	273	314	322	341	358	0.9
Australasia	90	99	99	103	109	113	117	122	0.9
Total Industrialized	2,850	2,893	2,980	3,157	3,353	3,535	3,726	3,907	1.1
EE/FSU									
Former Soviet Union	991	636	613	583	627	666	702	746	0.8
Eastern Europe	299	230	228	243	262	270	274	277	0.8
Total EE/FSU	1,290	866	842	827	889	935	976	1,024	0.8
Developing Countries									
Developing Asia	1,065	1,427	1,474	1,659	2,028	2,426	2,849	3,377	3.5
China	620	792	805	930	1,143	1,391	1,670	2,031	3.9
India	153	222	230	273	331	386	436	494	3.2
South Korea	61	102	113	112	140	168	199	230	3.0
Other Asia	232	311	326	344	414	480	545	622	2.7
Middle East	229	269	283	323	379	434	490	565	2.8
Turkey	35	40	43	46	58	65	72	81	2.7
Africa	176	192	198	214	241	270	296	325	2.1
Central and South America	174	194	206	251	330	418	513	629	4.8
Brazil	57	64	71	73	96	121	151	187	4.1
Other Central/South America	117	130	135	178	236	297	362	442	5.1
Total Developing	1,646	2,083	2,161	2,447	2,978	3,547	4,148	4,886	3.5
Total World	5,786	5,841	5,983	6,430	7,220	8,018	8,850	9,817	2.1

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. The U.S. numbers include carbon emissions attributable to renewable energy sources.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table A19; and World Energy Projection System (1999).

Table A11. World Carbon Emissions from Oil Use by Region, Reference Case, 1990-2020
(Million Metric Tons)

Region/Country	History			Projections					Average Annual Percent Change, 1996-2020
	1990	1995	1996	2000	2005	2010	2015	2020	
Industrialized Countries									
North America	714	723	747	808	856	919	965	1,012	1.3
United States[a]	591	600	621	669	708	758	791	823	1.2
Canada	61	62	64	72	72	76	78	81	1.0
Mexico	62	61	62	67	75	84	95	109	2.4
Western Europe	477	478	483	510	523	538	552	565	0.7
United Kingdom	66	63	63	64	69	71	73	75	0.7
France	67	65	66	68	72	74	75	76	0.6
Germany	99	101	102	106	110	113	115	117	0.6
Italy	74	76	77	78	87	92	97	102	1.2
Netherlands	29	26	25	26	28	29	30	31	0.8
Other Western Europe	141	147	149	168	158	160	162	164	0.4
Industrialized Asia	219	218	221	214	222	235	247	260	0.7
Japan	179	174	179	171	173	183	191	200	0.5
Australasia	40	44	43	43	49	52	56	59	1.4
Total Industrialized	1,410	1,419	1,461	1,532	1,600	1,692	1,763	1,837	1.0
EE/FSU									
Former Soviet Union	335	174	165	165	168	176	185	194	0.7
Eastern Europe	69	47	48	56	58	60	61	61	1.0
Total EE/FSU	403	220	212	222	226	237	246	255	0.8
Developing Countries									
Developing Asia	310	396	416	476	544	651	765	854	3.0
China	98	106	113	145	159	204	257	279	3.8
India	45	56	59	67	92	108	125	146	3.8
South Korea	38	66	71	68	91	110	129	153	3.3
Other Asia	129	168	173	196	202	229	254	277	2.0
Middle East	154	174	181	195	244	280	319	365	3.0
Turkey	17	21	22	23	31	36	41	47	3.2
Africa	84	84	87	96	109	127	146	168	2.8
Central and South America	128	135	138	164	218	255	295	344	3.9
Brazil	46	49	51	51	62	76	92	112	3.4
Other Central/South America	82	85	87	113	157	179	202	231	4.2
Total Developing	677	789	821	932	1,115	1,313	1,524	1,731	3.2
Total World	2,490	2,429	2,485	2,686	2,941	3,242	3,533	3,823	1.8

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table A19; and World Energy Projection System (1999).

Table A12. World Carbon Emissions from Natural Gas Use by Region, Reference Case, 1990-2020
(Million Metric Tons)

Region/Country	History			Projections					Average Annual Percent Change, 1996-2020
	1990	1995	1996	2000	2005	2010	2015	2020	
Industrialized Countries									
North America	320	370	378	401	452	499	548	578	1.8
United States[a]	273	314	318	331	370	412	453	475	1.7
Canada	34	41	44	46	52	55	59	65	1.7
Mexico	13	15	15	23	30	33	36	38	3.8
Western Europe	139	172	193	222	260	294	335	382	2.9
United Kingdom	32	40	47	59	66	74	82	91	2.8
France	15	17	20	22	28	31	36	44	3.4
Germany	31	43	47	54	63	73	85	95	3.0
Italy	24	27	29	33	33	35	38	40	1.4
Netherlands	19	21	23	26	27	28	30	32	1.4
Other Western Europe	18	24	27	28	44	52	65	79	4.6
Industrialized Asia	41	48	51	49	73	70	79	86	2.2
Japan	29	35	37	33	56	53	62	68	2.5
Australasia	12	13	13	16	17	17	17	18	1.1
Total Industrialized	500	590	621	672	785	864	961	1,046	2.2
EE/FSU									
Former Soviet Union	323	262	264	262	304	337	373	419	2.0
Eastern Europe	41	36	39	47	63	83	100	119	4.7
Total EE/FSU	365	298	303	309	367	420	473	538	2.4
Developing Countries									
Developing Asia	40	69	79	94	180	248	340	437	7.4
China	7	9	10	20	43	65	106	142	11.7
India	6	10	11	20	31	45	62	82	8.6
South Korea	2	6	8	8	10	13	18	24	4.9
Other Asia	26	45	50	46	95	125	154	189	5.7
Middle East	55	73	80	103	110	127	143	160	2.9
Turkey	2	3	4	4	8	8	10	12	4.6
Africa	20	26	27	29	37	42	46	50	2.7
Central and South America	29	39	43	59	83	133	186	250	7.6
Brazil	1	2	3	5	14	26	38	52	12.5
Other Central/South America	28	37	40	55	69	107	148	199	6.9
Total Developing	145	208	229	284	409	549	716	896	5.9
Total World	1,009	1,095	1,152	1,265	1,561	1,833	2,150	2,483	3.3

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table A19; and World Energy Projection System (1999).

Table A13. World Carbon Emissions from Coal Use by Region, Reference Case, 1990-2020
(Million Metric Tons)

Region/Country	History			Projections					Average Annual Percent Change, 1996-2020
	1990	1995	1996	2000	2005	2010	2015	2020	
Industrialized Countries									
North America	516	536	562	623	638	659	688	723	1.1
United States[a]	481	498	524	585	599	618	644	676	1.1
Canada	31	32	32	32	31	31	33	36	0.5
Mexico	3	5	6	7	8	10	10	11	2.4
Western Europe	319	234	229	216	200	189	180	166	-1.3
United Kingdom	69	42	43	34	30	25	22	15	-4.3
France	20	15	15	12	8	5	4	3	-6.1
Germany	137	91	89	85	82	80	77	74	-0.8
Italy	15	12	10	11	12	11	11	10	-0.1
Netherlands	11	10	10	10	10	10	9	8	-0.9
Other Western Europe	67	63	61	64	60	59	57	56	-0.4
Industrialized Asia	105	113	117	113	128	130	132	134	0.6
Japan	66	72	74	70	84	86	87	89	0.7
Australasia	39	41	43	44	44	44	44	45	0.2
Total Industrialized	940	884	908	952	967	979	1,000	1,023	0.5
EE/FSU									
Former Soviet Union	333	201	185	157	155	152	144	133	-1.4
Eastern Europe	189	148	142	140	141	127	113	97	-1.6
Total EE/FSU	522	348	327	297	296	279	257	230	-1.4
Developing Countries									
Developing Asia	714	962	980	1,089	1,304	1,527	1,744	2,086	3.2
China	514	677	682	765	941	1,123	1,308	1,610	3.6
India	101	156	160	185	208	232	249	268	2.2
South Korea	21	30	34	37	38	45	51	53	1.8
Other Asia	78	98	103	102	117	127	137	155	1.7
Middle East	20	21	23	25	26	27	29	29	1.1
Turkey	16	16	17	19	19	21	22	22	1.1
Africa	74	82	84	88	95	100	103	107	1.0
Central and South America	17	20	25	28	29	30	32	35	1.4
Brazil	9	12	17	17	18	19	21	23	1.3
Other Central/South America	7	8	8	11	10	11	11	12	1.7
Total Developing	825	1,085	1,111	1,230	1,454	1,684	1,908	2,257	3.0
Total World	2,287	2,317	2,345	2,479	2,717	2,942	3,165	3,510	1.7

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table A19; and World Energy Projection System (1999).

Table A14. World Nuclear Generating Capacity by Region and Country, Reference Case, 1996-2020
(Megawatts)

Region/Country	History		Projections				
	1996	1997	2000	2005	2010	2015	2020
Industrialized							
North America							
United States	100,817	99,046	94,836	87,362	74,183	56,372	48,871
Canada	14,902	11,994	11,146	10,298	10,298	10,298	7,996
Mexico	1,308	1,308	1,308	1,308	1,308	1,308	1,308
Industrialized Asia							
Japan	42,369	43,850	43,691	44,487	54,273	53,376	53,596
Western Europe							
Belgium	5,712	5,712	5,712	5,712	5,712	4,358	3,966
Finland	2,355	2,560	2,815	2,815	2,815	2,815	1,535
France	59,948	62,853	63,103	62,870	64,320	64,320	61,455
Germany	22,282	22,282	22,282	21,302	17,339	14,294	14,294
Netherlands	504	449	449	449	449	0	0
Spain	7,207	7,415	7,415	7,262	6,822	6,822	2,902
Sweden	10,040	10,040	9,440	9,440	8,390	6,085	6,085
Switzerland	3,077	3,079	3,079	3,194	2,829	2,115	1,145
United Kingdom	12,928	12,968	12,968	12,968	11,862	11,647	10,558
Total Industrialized	**283,449**	**283,556**	**278,244**	**269,467**	**260,620**	**233,810**	**213,711**
EE/FSU							
Eastern Europe							
Bulgaria	3,538	3,538	3,538	3,538	2,722	2,722	2,722
Czech Republic	1,648	1,648	1,648	3,472	3,472	3,472	3,060
Hungary	1,729	1,729	1,729	1,729	1,729	1,729	1,729
Romania	650	650	650	1,300	1,300	1,300	1,300
Slovak Republic	1,632	1,632	2,456	2,048	1,640	1,640	1,640
Slovenia	632	632	632	632	632	0	0
Former Soviet Union							
Armenia	376	376	376	752	752	376	376
Belarus	0	0	0	0	0	0	0
Kazakhstan	70	70	70	0	0	0	0
Lithuania	2,370	2,370	2,370	2,370	2,370	2,370	1,185
Russia	19,843	19,843	22,668	21,101	21,479	21,707	19,325
Ukraine	13,765	13,765	12,115	12,140	12,140	14,040	9,500
Total EE/FSU	**46,253**	**46,253**	**48,252**	**49,082**	**48,236**	**49,356**	**40,837**

See notes at end of table.

Table A14. World Nuclear Generating Capacity by Region and Country, Reference Case, 1996-2020 (Continued)
(Megawatts)

Region/Country	History 1996	History 1997	Projections 2000	Projections 2005	Projections 2010	Projections 2015	Projections 2020
Developing Countries							
Developing Asia							
China	2,167	2,167	2,167	6,737	11,542	14,702	18,762
India	1,695	1,695	1,897	2,653	4,463	5,913	7,726
Indonesia	0	0	0	0	0	0	0
Korea, North	0	0	0	0	950	950	950
Korea, South	9,120	9,770	12,990	13,940	14,890	16,234	15,000
Pakistan	125	125	125	300	600	600	600
Philippines	0	0	0	0	0	0	0
Taiwan	4,884	4,884	4,884	7,384	7,384	7,384	6,176
Thailand	0	0	0	0	0	0	0
Vietnam	0	0	0	0	0	0	0
Central and South America							
Argentina	935	935	935	1,292	1,292	1,292	692
Brazil	626	626	626	1,871	1,871	1,871	1,245
Cuba	0	0	0	0	0	0	0
Middle East	0	0	0	0	0	0	0
Iran	0	0	0	0	2,146	2,146	2,146
Egypt	0	0	0	0	0	0	0
Turkey	0	0	0	0	0	1,300	1,300
Africa							
South Africa	1,842	1,842	1,842	1,842	1,842	1,842	1,842
Total Developing	**21,394**	**22,044**	**25,466**	**36,019**	**46,980**	**54,234**	**56,439**
Total World	**351,096**	**351,853**	**351,962**	**354,568**	**355,836**	**337,400**	**310,987**

Note: EE/FSU = Eastern Europe/Former Soviet Union.

Sources: **History:** International Atomic Energy Agency, *Nuclear Power Reactors in the World* (Vienna, Austria, April 1998). **Projections:** Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, based on detailed assessments of country-specific nuclear power plants.

Table A15. World Total Energy Consumption in Oil-Equivalent Units by Region, Reference Case, 1990-2020
(Million Tons Oil Equivalent)

Region/Country	History			Projections					Average Annual Percent Change, 1996-2020
	1990	1995	1996	2000	2005	2010	2015	2020	
Industrialized Countries									
North America	**2,513**	**2,723**	**2,811**	**3,005**	**3,198**	**3,399**	**3,561**	**3,717**	**1.2**
United States[a]	2,115	2,278	2,352	2,500	2,638	2,793	2,911	3,021	1.0
Canada	274	307	317	341	367	389	407	426	1.2
Mexico	124	138	142	164	193	217	242	270	2.7
Western Europe	**1,511**	**1,570**	**1,613**	**1,704**	**1,797**	**1,880**	**1,964**	**2,053**	**1.0**
United Kingdom	236	233	249	264	282	296	309	323	1.1
France	235	257	267	278	290	302	315	327	0.9
Germany	372	358	365	383	404	424	444	465	1.0
Italy	168	179	183	192	205	217	229	242	1.2
Netherlands	83	89	92	99	104	110	115	121	1.1
Other Western Europe	419	453	458	489	512	531	551	574	1.0
Industrialized Asia	**579**	**663**	**678**	**662**	**745**	**778**	**817**	**853**	**1.0**
Japan	456	523	539	514	588	614	645	673	0.9
Australasia	123	140	139	148	157	164	172	180	1.1
Total Industrialized	**4,604**	**4,955**	**5,103**	**5,371**	**5,740**	**6,058**	**6,341**	**6,623**	**1.1**
EE/FSU									
Former Soviet Union	1,473	1,027	1,003	968	1,053	1,126	1,204	1,287	1.0
Eastern Europe	382	312	316	341	380	412	440	471	1.7
Total EE/FSU	**1,855**	**1,340**	**1,319**	**1,309**	**1,434**	**1,538**	**1,644**	**1,758**	**1.2**
Developing Countries									
Developing Asia	**1,294**	**1,611**	**1,879**	**2,130**	**2,673**	**3,217**	**3,805**	**4,483**	**3.7**
China	680	917	935	1,098	1,386	1,703	2,060	2,478	4.1
India	195	279	291	356	442	523	610	710	3.8
South Korea	93	165	180	190	237	285	335	387	3.2
Other Asia	327	449	473	487	608	706	800	907	2.8
Middle East	**331**	**413**	**436**	**507**	**591**	**681**	**772**	**874**	**2.9**
Turkey	50	63	67	80	92	106	121	138	3.0
Africa	**233**	**270**	**279**	**303**	**347**	**391**	**432**	**477**	**2.3**
Central and South America	**346**	**423**	**446**	**529**	**663**	**821**	**993**	**1,201**	**4.2**
Brazil	136	161	173	178	219	267	320	384	3.4
Other Central/South America	210	262	274	351	445	554	673	818	4.7
Total Developing	**2,203**	**2,917**	**3,039**	**3,468**	**4,274**	**5,110**	**6,002**	**7,035**	**3.6**
Total World	**8,663**	**9,212**	**9,461**	**10,149**	**11,448**	**12,705**	**13,987**	**15,417**	**2.1**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table A1; and World Energy Projection System (1999).

Table A16. World Population by Region, Reference Case, 1990-2020
(Millions)

Region/Country	History			Projections					Percent Change, 1996-2020	
	1990	1995	1996	2000	2005	2010	2015	2020	Annual Average	Total
Industrialized Countries										
North America	**361**	**382**	**384**	**388**	**405**	**425**	**444**	**464**	**0.8**	**20.9**
United States[a]	250	264	263	266	275	287	298	311	0.7	18.0
Canada	28	29	29	30	31	32	33	34	0.6	16.3
Mexico	83	90	91	93	99	106	113	119	1.1	30.8
Western Europe	**377**	**382**	**384**	**384**	**388**	**389**	**388**	**387**	**0.0**	**0.8**
United Kingdom	58	58	58	58	58	59	59	59	0.1	1.8
France	57	58	58	59	59	60	60	60	0.1	3.5
Germany	79	81	82	82	83	83	82	82	0.0	0.6
Italy	57	57	57	57	57	57	56	55	-0.2	-4.5
Netherlands	15	15	15	16	16	16	16	16	0.2	4.5
Other Western Europe	111	113	113	113	115	115	115	115	0.1	1.3
Industrialized Asia	**144**	**146**	**146**	**147**	**149**	**151**	**152**	**152**	**0.2**	**3.8**
Japan	124	125	125	125	126	127	127	126	0.0	0.6
Australasia	20	21	21	22	23	24	25	26	0.9	22.7
Total Industrialized	**882**	**911**	**914**	**920**	**941**	**964**	**985**	**1,003**	**0.4**	**9.7**
EE/FSU										
Former Soviet Union	290	293	293	293	294	294	296	297	0.1	1.3
Eastern Europe	123	122	122	122	122	122	122	122	0.0	0.1
Total EE/FSU	**412**	**415**	**415**	**415**	**416**	**416**	**416**	**419**	**0.0**	**1.0**
Developing Countries										
Developing Asia	**2,810**	**2,983**	**3,032**	**3,476**	**3,250**	**3,464**	**3,649**	**3,832**	**1.0**	**26.4**
China	1,155	1,207	1,220	1,231	1,276	1,322	1,365	1,409	0.6	15.5
India	851	913	929	945	1,007	1,062	1,152	1,212	1.1	30.4
South Korea	43	44	45	45	47	49	50	51	0.5	13.6
Other Asia	761	819	838	1,255	920	1,001	1,081	1,160	1.4	38.5
Middle East	**198**	**219**	**225**	**230**	**252**	**284**	**316**	**349**	**1.9**	**56.3**
Turkey	56	60	61	62	66	70	75	79	1.1	29.1
Africa	**629**	**700**	**719**	**740**	**820**	**931**	**1,052**	**1,181**	**2.1**	**64.2**
Central and South America	**351**	**375**	**382**	**388**	**412**	**442**	**472**	**501**	**1.1**	**31.3**
Brazil	148	157	159	161	169	179	190	200	1.0	25.5
Other Central/South America	203	219	223	227	243	262	282	302	1.3	35.5
Total Developing	**3,988**	**4,279**	**4,358**	**4,834**	**4,734**	**5,110**	**5,489**	**5,864**	**1.2**	**34.6**
Total World	**5,282**	**5,604**	**5,687**	**6,168**	**6,091**	**6,491**	**6,891**	**7,286**	**1.0**	**28.1**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.
Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding.
Source: United Nations, *The Sex and Age Distribution of the World Populations: The 1996 Revision* (New York, NY, 1997).

Appendix B

High Economic Growth Case Projections:

- World Energy Consumption
- Gross Domestic Product
- Carbon Emissions
- Nuclear Power Capacity

Table B1. World Total Energy Consumption by Region, High Economic Growth Case, 1990-2020
(Quadrillion Btu)

Region/Country	History			Projections					Average Annual Percent Change, 1996-2020
	1990	1995	1996	2000	2005	2010	2015	2020	
Industrialized Countries									
North America	**99.7**	**106.0**	**111.6**	**120.2**	**130.6**	**141.3**	**150.6**	**160.6**	**1.5**
United States[a]	83.9	90.4	93.3	99.6	107.4	115.3	122.3	129.4	1.4
Canada	10.9	12.2	12.6	13.9	15.3	16.6	17.7	19.0	1.7
Mexico	4.9	5.5	5.6	6.7	8.2	9.4	10.8	12.3	3.3
Western Europe	**60.0**	**62.3**	**64.0**	**69.0**	**74.3**	**79.2**	**84.3**	**89.8**	**1.4**
United Kingdom	9.4	9.3	9.9	10.7	11.7	12.5	13.4	14.2	1.5
France	9.3	10.2	10.6	11.2	11.9	12.7	13.4	14.2	1.2
Germany	14.7	14.2	14.5	15.5	16.7	17.8	19.0	20.3	1.4
Italy	6.7	7.1	7.2	7.8	8.5	9.3	10.0	10.8	1.7
Netherlands	3.3	3.5	3.7	4.0	4.3	4.6	5.0	5.3	1.6
Other Western Europe	16.6	18.0	18.2	19.8	21.2	22.3	23.5	24.9	1.3
Industrialized Asia	**23.0**	**26.3**	**26.9**	**27.0**	**32.0**	**34.0**	**36.4**	**38.7**	**1.5**
Japan	18.1	20.8	21.4	21.0	25.5	27.1	29.0	30.8	1.5
Australasia	4.9	5.6	5.5	6.0	6.5	7.0	7.4	7.9	1.5
Total Industrialized	**182.7**	**196.6**	**202.5**	**216.2**	**237.2**	**254.5**	**271.5**	**289.2**	**1.5**
EE/FSU									
Former Soviet Union	58.5	40.8	39.8	40.6	47.6	54.3	61.9	70.7	2.4
Eastern Europe	15.2	12.4	12.6	14.2	16.9	19.4	21.9	24.8	2.9
Total EE/FSU	**73.6**	**53.2**	**52.4**	**54.8**	**64.5**	**73.7**	**83.8**	**95.4**	**2.5**
Developing Countries									
Developing Asia	**51.4**	**71.8**	**74.5**	**88.9**	**117.5**	**148.0**	**182.8**	**224.8**	**4.7**
China	27.0	36.4	37.1	45.3	59.9	77.0	97.4	122.4	5.1
India	7.7	11.1	11.5	14.9	19.7	24.5	29.6	36.3	4.9
South Korea	3.7	6.5	7.2	8.2	10.7	13.5	16.6	20.0	4.4
Other Asia	13.0	17.8	18.8	20.5	27.1	32.9	38.9	46.1	3.8
Middle East	**13.1**	**16.4**	**17.3**	**21.9**	**26.9**	**32.5**	**38.5**	**45.6**	**4.1**
Turkey	2.0	2.5	2.7	3.3	4.0	4.9	5.8	7.0	4.1
Africa	**9.2**	**10.7**	**11.1**	**12.7**	**15.3**	**18.0**	**20.7**	**23.8**	**3.2**
Central and South America	**13.7**	**16.8**	**17.7**	**23.5**	**31.4**	**41.4**	**53.3**	**68.6**	**5.8**
Brazil	5.4	6.4	6.8	7.4	9.7	12.6	16.1	20.5	4.7
Other Central/South America	8.3	10.4	10.9	16.1	21.8	28.8	37.2	48.1	6.4
Total Developing	**87.4**	**115.7**	**120.6**	**147.1**	**191.1**	**239.9**	**295.4**	**362.8**	**4.7**
Total World	**343.8**	**365.6**	**375.5**	**418.1**	**492.8**	**568.1**	**650.8**	**747.4**	**2.9**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Energy totals include net imports of coal coke and electricity generated from biomass in the United States. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table B1; and World Energy Projection System (1999).

Table B2. World Total Energy Consumption by Region and Fuel, High Economic Growth Case, 1990-2020
(Quadrillion Btu)

Region/Country	History			Projections					Average Annual Percent Change, 1996-2020
	1990	1995	1996	2000	2005	2010	2015	2020	
Industrialized Countries									
North America									
Oil	40.4	41.8	43.2	47.4	51.4	56.2	60.4	64.8	1.7
Natural Gas	22.7	26.2	26.8	28.5	33.1	37.2	41.4	44.1	2.1
Coal	20.4	21.1	22.0	24.4	25.4	26.4	28.1	30.3	1.3
Nuclear	7.0	8.3	8.2	8.0	7.7	6.9	5.5	4.8	-2.2
Other	9.2	10.6	11.4	11.9	13.3	14.5	15.5	16.7	1.6
Total	**99.7**	**108.0**	**111.6**	**120.2**	**130.8**	**141.3**	**150.8**	**160.6**	**1.5**
Western Europe									
Oil	25.8	28.0	28.2	30.4	31.9	33.4	34.9	36.4	1.1
Natural Gas	9.9	12.2	13.7	16.0	19.2	22.1	25.7	29.9	3.3
Coal	12.5	9.1	9.1	8.6	8.1	7.8	7.5	7.1	-1.0
Nuclear	7.4	8.2	8.6	9.1	9.2	9.2	8.6	8.0	-0.3
Other	4.4	4.8	4.5	4.9	5.9	6.7	7.6	8.4	2.8
Total	**60.0**	**62.3**	**64.0**	**69.0**	**74.3**	**79.2**	**84.3**	**89.8**	**1.4**
Industrialized Asia									
Oil	12.5	14.1	14.3	14.3	15.6	16.7	17.9	19.2	1.2
Natural Gas	2.9	3.3	3.6	3.5	5.5	5.4	6.2	6.9	2.8
Coal	4.2	4.6	4.7	4.7	5.6	5.8	6.0	6.2	1.1
Nuclear	2.0	2.8	2.9	3.1	3.4	4.2	4.2	4.2	1.6
Other	1.4	1.4	1.4	1.3	1.9	1.9	2.1	2.3	2.1
Total	**23.0**	**26.3**	**26.9**	**27.0**	**32.0**	**34.0**	**36.4**	**38.7**	**1.5**
Total Industrialized									
Oil	78.7	83.9	85.7	92.1	98.8	106.4	113.2	120.4	1.4
Natural Gas	35.5	41.8	44.0	48.1	57.9	64.8	73.3	80.9	2.6
Coal	37.2	34.8	35.8	37.7	39.1	40.0	41.6	43.5	0.8
Nuclear	18.3	19.4	19.8	20.3	20.3	20.2	18.3	17.0	-0.6
Other	15.0	16.8	17.2	18.1	21.1	23.2	25.2	27.3	1.9
Total	**182.7**	**195.6**	**202.5**	**216.2**	**237.2**	**254.5**	**271.5**	**289.2**	**1.5**
EE/FSU									
Oil	21.0	12.4	12.0	13.2	14.5	16.1	17.8	19.7	2.1
Natural Gas	26.0	21.4	21.7	23.4	29.9	36.5	43.7	53.0	3.8
Coal	20.8	13.8	13.0	12.4	13.3	13.3	13.1	12.4	-0.2
Nuclear	2.9	2.5	2.8	3.0	3.3	3.6	4.0	3.7	1.1
Other	2.8	3.0	2.9	2.8	3.5	4.1	5.2	6.7	3.6
Total	**73.6**	**53.2**	**52.4**	**54.8**	**64.5**	**73.7**	**83.8**	**95.4**	**2.5**
Developing Countries									
Developing Asia									
Oil	16.0	23.6	24.8	29.8	35.9	44.9	55.1	64.3	4.0
Natural Gas	3.0	5.1	5.7	7.2	14.5	21.0	30.1	40.3	8.5
Coal	28.1	38.0	38.7	45.3	57.1	69.9	83.4	104.1	4.2
Nuclear	0.9	1.2	1.3	1.6	2.3	3.0	3.6	4.0	4.8
Other	3.2	4.0	4.0	5.0	7.7	9.1	10.6	12.1	4.7
Total	**51.4**	**71.8**	**74.5**	**88.9**	**117.5**	**146.0**	**182.8**	**224.6**	**4.7**

See notes at end of table.

Table B2. World Total Energy Consumption by Region and Fuel, High Economic Growth Case, 1990-2020 (Continued)
(Quadrillion Btu)

Region/Country	History 1990	History 1995	History 1996	Projections 2000	Projections 2005	Projections 2010	Projections 2015	Projections 2020	Average Annual Percent Change, 1996-2020
Developing Countries (Continued)									
Middle East									
Oil	8.1	9.8	10.1	11.9	15.7	18.9	22.5	26.9	4.2
Natural Gas	3.9	5.2	5.7	8.0	8.9	10.8	12.8	15.0	4.1
Coal	0.8	0.8	0.9	1.1	1.2	1.3	1.4	1.5	2.3
Nuclear	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.2	--
Other	0.4	0.5	0.6	1.0	1.1	1.4	1.6	1.9	5.2
Total	**13.1**	**16.4**	**17.3**	**21.9**	**26.9**	**32.5**	**38.5**	**45.6**	**4.1**
Africa									
Oil	4.2	4.8	5.0	5.9	6.9	8.5	10.1	12.1	3.8
Natural Gas	1.4	1.9	2.0	2.2	3.0	3.6	4.1	4.6	3.6
Coal	3.0	3.3	3.4	3.8	4.3	4.7	5.0	5.4	2.0
Nuclear	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.8
Other	0.6	0.6	0.6	0.8	1.0	1.2	1.3	1.5	3.8
Total	**9.2**	**10.7**	**11.1**	**12.7**	**15.3**	**18.0**	**20.7**	**23.8**	**3.2**
Central and South America									
Oil	6.9	8.0	8.1	10.9	15.4	19.2	23.5	29.2	5.5
Natural Gas	2.1	2.9	3.1	4.8	7.2	12.2	18.2	26.1	9.3
Coal	0.7	0.8	1.0	1.2	1.4	1.5	1.7	2.0	3.0
Nuclear	0.1	0.1	0.1	0.1	0.2	0.3	0.3	0.2	2.9
Other	3.9	5.1	5.4	6.5	7.3	8.3	9.5	11.1	3.1
Total	**13.7**	**16.8**	**17.7**	**23.5**	**31.4**	**41.4**	**53.3**	**68.6**	**5.8**
Total Developing Countries									
Oil	35.2	46.2	48.1	58.5	73.8	91.4	111.3	132.5	4.3
Natural Gas	10.5	15.0	16.5	22.2	33.6	47.8	65.2	86.0	7.1
Coal	32.5	42.9	43.9	51.3	63.9	77.4	91.6	113.0	4.0
Nuclear	1.1	1.4	1.5	1.8	2.6	3.5	4.2	4.6	4.7
Other	8.1	10.2	10.6	13.2	17.1	19.9	23.1	26.7	3.9
Total	**87.4**	**115.7**	**120.6**	**147.1**	**191.1**	**239.9**	**295.4**	**362.8**	**4.7**
Total World									
Oil	134.9	142.5	145.7	163.8	187.2	213.9	242.3	272.6	2.6
Natural Gas	72.0	78.1	82.2	93.6	121.4	148.9	182.2	219.9	4.2
Coal	90.6	91.6	92.8	101.4	116.3	130.7	146.3	169.0	2.5
Nuclear	20.4	23.3	24.1	25.1	26.3	27.3	26.5	25.2	0.2
Other	25.9	30.1	30.7	34.2	41.7	47.3	53.5	60.6	2.9
Total	**343.8**	**365.6**	**375.5**	**418.1**	**492.8**	**568.1**	**650.8**	**747.4**	**2.9**

*Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Energy totals include net imports of coal coke and electricity generated from biomass in the United States. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table B1; and World Energy Projection System (1999).

Table B3. World Gross Domestic Product (GDP) by Region, High Economic Growth Case, 1990-2020
(Billion 1997 Dollars)

Region/Country	History			Projections					Percent Change, 1996-2020	
	1990	1995	1996	2000	2005	2010	2015	2020	Annual Average	Total
Industrialized Countries										
North America	**7,726**	**8,492**	**8,778**	**10,249**	**12,148**	**14,483**	**16,739**	**19,207**	**3.3**	**118.8**
United States[a]	6,848	7,546	7,806	9,081	10,881	12,652	14,502	16,468	3.2	111.0
Canada	546	588	596	697	845	1,012	1,174	1,362	3.5	128.7
Mexico	332	358	377	471	621	819	1,062	1,377	5.6	265.7
Western Europe	**7,665**	**8,118**	**8,258**	**9,498**	**11,318**	**13,379**	**15,764**	**18,577**	**3.4**	**125.0**
United Kingdom	1,143	1,219	1,246	1,427	1,727	2,046	2,412	2,843	3.5	128.2
France	1,269	1,340	1,361	1,556	1,821	2,140	2,493	2,903	3.2	113.3
Germany	1,839	2,019	2,045	2,331	2,798	3,324	3,939	4,668	3.5	128.3
Italy	1,060	1,121	1,128	1,277	1,524	1,800	2,122	2,500	3.4	121.6
Netherlands	303	336	347	410	487	573	674	793	3.5	128.9
Other Western Europe	1,951	2,083	2,132	2,497	2,962	3,496	4,125	4,869	3.5	128.4
Industrialized Asia	**4,094**	**4,424**	**4,602**	**4,568**	**5,366**	**6,371**	**7,546**	**8,937**	**2.8**	**94.2**
Japan	3,720	3,994	4,158	4,057	4,764	5,667	6,718	7,963	2.7	91.5
Australasia	374	429	444	511	602	704	828	974	3.3	119.2
Total Industrialized	**19,384**	**21,034**	**21,638**	**24,315**	**28,832**	**34,233**	**40,049**	**46,721**	**3.3**	**115.9**
EE/FSU										
Former Soviet Union	1,049	621	594	619	839	1,126	1,511	2,028	5.3	241.6
Eastern Europe	356	333	347	459	678	961	1,322	1,818	7.1	424.3
Total EE/FSU	**1,404**	**954**	**940**	**1,076**	**1,517**	**2,087**	**2,833**	**3,846**	**6.0**	**309.0**
Developing Countries										
Developing Asia	**1,726**	**2,536**	**2,727**	**3,259**	**4,736**	**6,718**	**9,351**	**13,037**	**6.7**	**378.0**
China	440	777	851	1,131	1,737	2,572	3,739	5,436	8.0	538.5
India	278	345	370	478	663	914	1,257	1,729	6.6	367.4
South Korea	273	392	419	461	671	954	1,331	1,855	6.4	342.4
Other Asia	734	1,023	1,087	1,189	1,665	2,277	3,024	4,017	5.6	269.7
Middle East	**378**	**460**	**487**	**571**	**763**	**1,016**	**1,335**	**1,755**	**5.5**	**260.4**
Turkey	143	167	179	229	302	400	532	708	5.9	295.5
Africa	**244**	**258**	**267**	**306**	**407**	**533**	**684**	**879**	**5.1**	**229.2**
Central and South America	**1,116**	**1,349**	**1,392**	**1,608**	**2,218**	**3,033**	**4,060**	**5,436**	**5.8**	**290.5**
Brazil	660	756	778	857	1,157	1,558	2,065	2,737	5.4	251.8
Other Central/South America	457	593	614	751	1,062	1,475	1,995	2,699	6.4	339.4
Total Developing	**3,465**	**4,603**	**4,873**	**5,745**	**8,124**	**11,300**	**15,430**	**21,107**	**6.3**	**333.1**
Total World	**24,253**	**26,592**	**27,452**	**31,138**	**38,474**	**47,620**	**58,311**	**71,674**	**4.1**	**161.1**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding.

Sources: **History:** The WEFA Group, *World Economic Outlook: 20-Year Extension* (Eddystone, PA, April 1997). **Projections:** Standard & Poor's DRI, *World Economic Outlook*, Vol. 1 (Lexington, MA, 3rd Quarter 1998); Energy Information Administration (EIA), *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table B20; and EIA, World Energy Projection System (1999).

Table B4. World Oil Consumption by Region, High Economic Growth Case, 1990-2020
(Million Barrels per Day)

Region/Country	History 1990	1995	1996	Projections 2000	2005	2010	2015	2020	Average Annual Percent Change, 1996-2020
Industrialized Countries									
North America	**20.4**	**21.3**	**22.0**	**24.2**	**26.3**	**28.8**	**30.9**	**33.2**	**1.7**
United States[a]	17.0	17.7	18.3	20.0	21.7	23.7	25.2	26.8	1.6
Canada	1.7	1.8	1.8	2.1	2.1	2.3	2.4	2.5	1.5
Mexico	1.7	1.9	1.9	2.1	2.4	2.8	3.2	3.8	2.9
Western Europe	**12.5**	**13.5**	**13.7**	**14.7**	**15.4**	**16.2**	**16.9**	**17.7**	**1.1**
United Kingdom	1.8	1.8	1.8	1.9	2.1	2.2	2.3	2.4	1.2
France	1.8	1.9	1.9	2.0	2.2	2.3	2.3	2.4	0.9
Germany	2.7	2.9	2.9	3.1	3.3	3.4	3.5	3.7	1.0
Italy	1.9	2.0	2.1	2.1	2.4	2.7	2.9	3.1	1.7
Netherlands	0.7	0.8	0.8	0.8	0.9	0.9	1.0	1.0	1.3
Other Western Europe	3.6	4.1	4.1	4.8	4.6	4.7	4.8	5.0	0.8
Industrialized Asia	**6.2**	**7.0**	**7.1**	**7.0**	**7.7**	**8.2**	**8.8**	**9.4**	**1.2**
Japan	5.1	5.7	5.9	5.8	6.2	6.7	7.1	7.6	1.1
Australasia	1.0	1.2	1.2	1.2	1.4	1.6	1.7	1.9	1.8
Total Industrialized	**39.0**	**41.8**	**42.7**	**46.0**	**49.4**	**53.2**	**56.7**	**60.3**	**1.4**
EE/FSU									
Former Soviet Union	8.4	4.6	4.4	4.6	5.1	5.7	6.4	7.1	2.1
Eastern Europe	1.6	1.3	1.3	1.6	1.8	2.0	2.1	2.2	2.2
Total EE/FSU	**10.0**	**5.9**	**5.7**	**6.3**	**6.9**	**7.7**	**8.5**	**9.4**	**2.1**
Developing Countries									
Developing Asia	**7.6**	**11.3**	**11.9**	**14.3**	**17.3**	**21.6**	**26.6**	**31.0**	**4.1**
China	2.3	3.3	3.5	4.7	6.4	7.3	9.6	10.9	4.8
India	1.2	1.6	1.7	2.0	2.9	3.6	4.4	5.3	4.9
South Korea	1.0	2.0	2.2	2.3	3.2	4.0	4.9	6.1	4.4
Other Asia	3.1	4.3	4.5	5.3	5.7	6.7	7.7	8.7	2.8
Middle East	**3.9**	**4.7**	**4.8**	**5.7**	**7.5**	**9.0**	**10.7**	**12.8**	**4.2**
Turkey	0.5	0.6	0.6	0.7	1.0	1.2	1.4	1.7	4.3
Africa	**2.1**	**2.3**	**2.4**	**2.8**	**3.4**	**4.1**	**4.9**	**5.9**	**3.8**
Central and South America	**3.4**	**3.9**	**4.0**	**5.3**	**7.6**	**9.4**	**11.6**	**14.3**	**5.5**
Brazil	1.3	1.5	1.5	1.6	2.1	2.7	3.5	4.6	4.7
Other Central/South America	2.1	2.4	2.5	3.7	5.5	6.7	8.0	9.8	5.9
Total Developing	**17.0**	**22.2**	**23.1**	**28.2**	**35.7**	**44.2**	**53.7**	**64.0**	**4.3**
Total World	**66.0**	**69.9**	**71.5**	**80.5**	**92.0**	**105.1**	**118.9**	**133.7**	**2.6**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table B21; and World Energy Projection System (1999).

Table B5. World Natural Gas Consumption by Region, High Economic Growth Case, 1990-2020
(Trillion Cubic Feet)

Region/Country	History			Projections					Average Annual Percent Change, 1996-2020
	1990	1995	1996	2000	2005	2010	2015	2020	
Industrialized Countries									
North America	22.0	25.4	26.0	27.6	32.1	36.1	40.2	42.8	2.1
United States[a]	18.7	21.6	21.9	22.7	26.2	29.7	33.0	34.8	1.9
Canada	2.4	2.9	3.1	3.4	3.8	4.1	4.5	5.1	2.2
Mexico	0.9	1.0	1.0	1.5	2.1	2.3	2.6	2.9	4.4
Western Europe	10.1	12.4	13.8	16.2	19.4	22.3	25.9	30.2	3.3
United Kingdom	2.1	2.7	3.2	4.0	4.7	5.3	6.0	6.8	3.2
France	1.0	1.2	1.3	1.5	1.8	2.2	2.6	3.2	3.8
Germany	2.7	3.4	3.7	4.3	5.1	6.1	7.2	8.2	3.4
Italy	1.7	1.9	2.0	2.3	2.4	2.6	2.8	3.1	1.9
Netherlands	1.5	1.7	1.9	2.1	2.3	2.4	2.7	2.9	1.8
Other Western Europe	1.2	1.6	1.8	1.9	3.1	3.6	4.6	5.7	5.0
Industrialized Asia	2.6	3.1	3.3	3.3	5.1	5.0	5.7	6.3	2.8
Japan	1.9	2.2	2.4	2.1	3.9	3.8	4.5	5.0	3.2
Australasia	0.8	0.9	0.9	1.1	1.2	1.2	1.2	1.3	1.6
Total Industrialized	34.8	41.0	43.1	47.1	56.6	63.4	71.8	79.3	2.6
EE/FSU									
Former Soviet Union	25.0	20.6	20.7	21.7	27.3	32.2	38.1	45.6	3.3
Eastern Europe	3.1	2.7	2.9	3.7	5.3	7.4	9.4	11.8	6.0
Total EE/FSU	28.1	23.4	23.7	25.4	32.5	39.6	47.4	57.5	3.8
Developing Countries									
Developing Asia	3.0	4.7	5.3	6.6	13.4	19.3	27.5	36.7	8.4
China	0.5	0.6	0.7	1.4	3.1	4.9	8.4	11.8	12.7
India	0.4	0.6	0.7	1.3	2.1	3.3	4.7	6.5	9.7
South Korea	0.1	0.3	0.5	0.7	0.9	1.3	1.8	2.5	7.3
Other Asia	1.9	3.2	3.5	3.2	7.2	9.8	12.5	15.9	6.5
Middle East	3.7	5.0	5.4	7.6	8.5	10.3	12.2	14.3	4.1
Turkey	0.1	0.2	0.3	0.6	0.6	0.8	1.0	1.4	7.0
Africa	1.4	1.7	1.8	2.0	2.7	3.2	3.7	4.2	3.6
Central and South America	2.0	2.6	2.9	4.5	6.7	11.3	16.9	24.2	9.3
Brazil	0.1	0.2	0.2	0.3	1.1	2.1	3.2	4.7	13.9
Other Central/South America	1.9	2.4	2.7	4.1	5.6	9.3	13.7	19.6	8.6
Total Developing	10.1	14.0	15.4	20.7	31.3	44.2	60.3	79.4	7.1
Total World	73.0	78.3	82.2	93.2	120.4	147.2	179.5	216.2	4.1

[a]*Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.*

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country. To convert cubic feet to cubic meters, divide each number in the table by 35.315.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table B13; and World Energy Projection System (1999).

Table B6. World Coal Consumption by Region, High Economic Growth Case, 1990-2020
(Million Short Tons)

Region/Country	History			Projections					Average Annual Percent Change, 1996-2020
	1990	1995	1996	2000	2005	2010	2015	2020	
Industrialized Countries									
North America	**957**	**1,013**	**1,056**	**1,172**	**1,222**	**1,267**	**1,357**	**1,466**	**1.4**
United States[a]	896	941	983	1,097	1,142	1,182	1,263	1,363	1.4
Canada	55	59	60	60	60	61	67	75	1.0
Mexico	7	13	14	15	20	25	26	28	3.0
Western Europe	**898**	**607**	**600**	**567**	**536**	**516**	**496**	**469**	**-1.0**
United Kingdom	121	79	61	65	58	50	44	31	-3.9
France	36	26	26	20	14	9	8	6	-5.7
Germany	528	298	290	283	278	274	270	265	-0.4
Italy	25	20	19	20	21	21	21	20	0.2
Netherlands	15	15	15	15	14	15	14	13	-0.6
Other Western Europe	173	170	170	173	165	166	163	161	-0.2
Industrialized Asia	**233**	**257**	**266**	**266**	**309**	**319**	**330**	**341**	**1.0**
Japan	125	140	144	139	178	185	192	199	1.3
Australasia	108	117	121	127	131	134	138	142	0.7
Total Industrialized	**2,088**	**1,876**	**1,922**	**2,005**	**2,067**	**2,101**	**2,185**	**2,276**	**0.7**
EE/FSU									
Former Soviet Union	848	508	472	422	450	472	477	469	0.0
Eastern Europe	523	426	413	430	462	437	413	375	-0.4
Total EE/FSU	**1,372**	**934**	**885**	**851**	**912**	**909**	**890**	**844**	**-0.2**
Developing Countries									
Developing Asia	**1,555**	**2,030**	**2,065**	**2,405**	**3,033**	**3,723**	**4,452**	**5,572**	**4.2**
China	1,124	1,489	1,500	1,751	2,254	2,814	3,428	4,405	4.6
India	242	312	321	393	468	549	614	691	3.2
South Korea	42	51	58	68	74	92	108	117	3.0
Other Asia	148	178	186	194	236	268	302	359	2.8
Middle East	**66**	**76**	**80**	**97**	**105**	**116**	**128**	**137**	**2.3**
Turkey	60	67	72	83	89	103	111	118	2.1
Africa	**152**	**172**	**174**	**194**	**220**	**241**	**260**	**279**	**2.0**
Central and South America	**30**	**32**	**40**	**51**	**56**	**63**	**71**	**82**	**3.0**
Brazil	17	19	27	29	34	37	43	49	2.5
Other Central/South America	13	13	13	22	23	26	28	32	3.8
Total Developing	**1,803**	**2,310**	**2,360**	**2,748**	**3,415**	**4,143**	**4,910**	**6,069**	**4.0**
Total World	**5,263**	**5,120**	**5,167**	**5,603**	**6,393**	**7,154**	**7,985**	**9,190**	**2.4**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country. To convert short tons to metric tons, divide each number in the table by 1.102.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table B16; and World Energy Projection System (1999).

Table B7. World Nuclear Energy Consumption by Region, High Economic Growth Case, 1990-2020
(Billion Kilowatthours)

Region/Country	History			Projections					Average Annual Percent Change, 1996-2020
	1990	1995	1996	2000	2005	2010	2015	2020	
Industrialized Countries									
North America	649	774	770	749	714	639	506	445	-2.3
United States[a]	577	673	675	659	630	554	419	373	-2.4
Canada	69	93	88	81	75	77	78	63	-1.4
Mexico	3	8	7	8	9	9	9	9	0.9
Western Europe	703	785	824	868	880	872	820	765	-0.3
United Kingdom	59	77	82	84	86	85	83	77	-0.2
France	298	358	376	407	416	431	442	433	0.6
Germany	145	146	154	162	157	140	114	116	-1.2
Italy	0	0	0	0	0	0	0	0	0.0
Netherlands	3	4	4	3	3	3	0	0	-100.0
Other Western Europe	198	200	208	211	215	209	177	134	-1.8
Industrialized Asia	192	277	283	308	333	409	412	412	1.6
Japan	192	277	283	308	333	409	412	412	1.6
Australasia	0	0	0	0	0	0	0	0	0.0
Total Industrialized	1,544	1,837	1,877	1,924	1,927	1,920	1,738	1,621	-0.6
EE/FSU									
Former Soviet Union	201	172	194	206	221	245	276	252	1.1
Eastern Europe	54	57	60	63	81	82	85	81	1.2
Total EE/FSU	256	229	254	269	303	328	361	332	1.1
Developing Countries									
Developing Asia	88	117	128	160	230	300	359	391	4.8
China	0	12	14	13	41	77	100	131	9.9
India	6	6	7	10	16	26	40	55	8.7
South Korea	50	64	70	100	114	128	145	138	2.9
Other Asia	32	34	37	37	60	69	73	66	2.5
Middle East	0	0	0	0	0	12	21	22	0.0
Turkey	0	0	0	0	0	0	8	8	0.0
Africa	8	11	12	12	13	13	14	14	0.8
Central and South America	9	9	9	11	18	22	23	18	2.9
Brazil	2	2	2	3	9	10	11	12	7.1
Other Central/South America	7	7	7	8	9	12	12	6	-0.4
Total Developing	105	138	149	183	261	347	416	445	4.7
Total World	1,905	2,203	2,280	2,376	2,490	2,595	2,516	2,398	0.2

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table B8; and World Energy Projection System (1999).

Table B8. World Consumption of Hydroelectricity and Other Renewable Energy by Region, High Economic Growth Case, 1990-2020
(Quadrillion Btu)

Region/Country	History 1990	History 1995	History 1996	Projections 2000	Projections 2005	Projections 2010	Projections 2015	Projections 2020	Average Annual Percent Change, 1996-2020
Industrialized Countries									
North America	9.2	10.6	11.4	11.9	13.3	14.5	15.5	16.7	1.6
United States[a]	5.8	6.8	7.3	7.3	7.6	8.1	8.6	9.2	1.0
Canada	3.1	3.4	3.6	4.1	5.0	5.6	6.0	6.4	2.4
Mexico	0.3	0.4	0.4	0.5	0.6	0.8	0.9	1.1	3.8
Western Europe	4.4	4.8	4.5	4.9	5.9	6.7	7.6	8.4	2.6
United Kingdom	0.1	0.1	0.0	0.1	0.2	0.3	0.4	0.5	10.6
France	0.6	0.7	0.7	0.7	0.8	1.0	1.0	1.1	2.2
Germany	0.2	0.2	0.2	0.3	0.5	0.7	0.9	1.0	6.7
Italy	0.4	0.5	0.5	0.5	0.6	0.6	0.7	0.7	1.5
Netherlands	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	19.4
Other Western Europe	3.2	3.3	3.1	3.2	3.8	4.0	4.3	4.7	1.8
Industrialized Asia	1.4	1.4	1.4	1.3	1.9	1.9	2.1	2.3	2.1
Japan	1.0	0.9	0.9	0.8	1.3	1.3	1.3	1.4	2.0
Australasia	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	2.4
Total Industrialized	15.0	16.8	17.2	18.1	21.1	23.2	25.2	27.3	1.9
EE/FSU									
Former Soviet Union	2.4	2.5	2.2	2.2	2.7	2.9	3.4	4.0	2.5
Eastern Europe	0.4	0.6	0.6	0.6	0.8	1.2	1.8	2.6	6.1
Total EE/FSU	2.8	3.0	2.9	2.8	3.5	4.1	5.2	6.7	3.6
Developing Countries									
Developing Asia	3.2	4.0	4.0	5.0	7.7	9.1	10.6	12.2	4.7
China	1.3	1.9	1.9	2.3	4.1	4.6	5.2	5.8	4.8
India	0.7	0.7	0.7	1.2	1.6	1.9	2.6	3.4	6.5
South Korea	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.3	7.4
Other Asia	1.1	1.3	1.3	1.4	1.9	2.2	2.6	2.9	3.3
Middle East	0.4	0.5	0.6	1.0	1.1	1.4	1.6	1.9	5.2
Turkey	0.2	0.4	0.4	0.5	0.5	0.6	0.7	0.8	2.6
Africa	0.6	0.6	0.6	0.8	1.0	1.2	1.3	1.5	3.8
Central and South America	3.9	5.1	5.4	6.5	7.3	8.3	9.5	11.1	3.1
Brazil	2.2	2.7	2.8	3.0	3.3	3.6	4.0	4.4	1.9
Other Central/South America	1.7	2.4	2.6	3.5	4.0	4.7	5.5	6.6	4.1
Total Developing	8.1	10.2	10.6	13.2	17.1	19.9	23.1	26.7	3.9
Total World	25.9	30.1	30.7	34.2	41.7	47.2	53.5	60.7	2.9

[a] Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country. U.S. totals include net electricity imports, methanol, and liquid hydrogen.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table B1; and World Energy Projection System (1999).

Table B9. World Electricity Consumption by Region, High Economic Growth Case, 1990-2020
(Billion Kilowatthours)

Region/Country	History			Projections					Average Annual Percent Change, 1996-2020
	1990	1995	1996	2000	2005	2010	2015	2020	
Industrialized Countries									
North America	**3,255**	**3,759**	**3,859**	**4,034**	**4,463**	**4,896**	**5,366**	**5,834**	**1.7**
United States[a]	2,713	3,163	3,243	3,346	3,678	4,003	4,355	4,687	1.5
Canada	435	462	473	518	563	620	676	737	1.9
Mexico	107	134	144	170	221	274	335	410	4.5
Western Europe	**2,064**	**2,209**	**2,245**	**2,430**	**2,746**	**3,071**	**3,432**	**3,828**	**2.2**
United Kingdom	286	301	305	326	368	407	449	493	2.0
France	324	365	378	409	456	510	567	625	2.1
Germany	485	473	473	493	561	634	715	801	2.2
Italy	222	247	248	284	335	391	454	524	3.2
Netherlands	71	82	85	96	110	125	142	160	2.7
Other Western Europe	675	742	756	822	915	1,004	1,105	1,225	2.0
Industrialized Asia	**930**	**1,068**	**1,090**	**1,178**	**1,444**	**1,583**	**1,738**	**1,890**	**2.3**
Japan	750	864	882	921	1,149	1,251	1,364	1,474	2.2
Australasia	180	204	207	257	295	332	374	415	2.9
Total Industrialized	**6,248**	**7,037**	**7,194**	**7,641**	**8,653**	**9,550**	**10,535**	**11,552**	**2.0**
EE/FSU									
Former Soviet Union	1,488	1,168	1,133	1,056	1,240	1,414	1,614	1,841	2.0
Eastern Europe	420	384	401	417	502	603	712	840	3.1
Total EE/FSU	**1,908**	**1,552**	**1,535**	**1,473**	**1,742**	**2,018**	**2,326**	**2,681**	**2.4**
Developing Countries									
Developing Asia	**1,268**	**1,912**	**2,002**	**2,474**	**3,443**	**4,665**	**5,955**	**7,731**	**5.8**
China	551	881	925	1,152	1,656	2,314	3,185	4,338	6.7
India	257	367	378	522	725	947	1,211	1,537	6.0
South Korea	95	162	181	206	271	341	419	505	4.4
Other Asia	365	501	519	594	791	963	1,141	1,351	4.1
Middle East	**272**	**371**	**386**	**479**	**601**	**743**	**903**	**1,085**	**4.4**
Turkey	51	76	85	135	198	304	397	574	8.3
Africa	**285**	**320**	**332**	**393**	**504**	**632**	**770**	**939**	**4.4**
Central and South America	**449**	**575**	**604**	**823**	**1,134**	**1,503**	**1,922**	**2,486**	**6.1**
Brazil	229	288	303	352	492	683	929	1,264	6.1
Other Central/South America	220	286	301	472	642	821	993	1,222	6.0
Total Developing	**2,274**	**3,178**	**3,324**	**4,169**	**5,683**	**7,444**	**9,550**	**12,241**	**5.6**
Total World	**10,431**	**11,767**	**12,053**	**13,283**	**16,077**	**19,011**	**22,411**	**26,474**	**3.3**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Electricity consumption equals generation plus imports minus exports minus distribution losses.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998), Table 6.2. **Projections:** EIA, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table 88; and World Energy Projection System (1999).

Table B10. World Carbon Emissions by Region, High Economic Growth Case, 1990-2020
(Million Metric Tons)

Region/Country	History			Projections					Average Annual Percent Change, 1996-2020
	1990	1995	1996	2000	2005	2010	2015	2020	
Industrialized Countries									
North America	**1,550**	**1,629**	**1,685**	**1,846**	**2,005**	**2,171**	**2,342**	**2,510**	**1.7**
United States[a]	1,346	1,412	1,461	1,591	1,721	1,858	1,997	2,124	1.6
Canada	126	135	140	155	163	174	187	204	1.6
Mexico	78	82	84	100	121	139	158	181	3.3
Western Europe	**936**	**885**	**904**	**967**	**1,025**	**1,085**	**1,154**	**1,229**	**1.3**
United Kingdom	167	145	153	160	173	182	191	201	1.1
France	103	97	101	104	110	116	124	136	1.2
Germany	267	235	238	249	264	281	299	315	1.2
Italy	113	116	116	125	138	149	160	172	1.7
Netherlands	59	57	58	63	68	71	75	79	1.3
Other Western Europe	226	234	237	268	273	287	305	328	1.3
Industrialized Asia	**364**	**379**	**389**	**387**	**457**	**478**	**514**	**548**	**1.4**
Japan	274	281	291	281	343	357	386	412	1.5
Australasia	90	99	99	106	115	121	128	136	1.3
Total Industrialized	**2,850**	**2,893**	**2,978**	**3,200**	**3,487**	**3,735**	**4,010**	**4,286**	**1.5**
EE/FSU									
Former Soviet Union	991	636	613	616	714	809	910	1,032	2.2
Eastern Europe	299	230	228	256	294	320	343	368	2.0
Total EE/FSU	**1,290**	**866**	**842**	**872**	**1,008**	**1,129**	**1,254**	**1,400**	**2.1**
Developing Countries									
Developing Asia	**1,065**	**1,427**	**1,474**	**1,745**	**2,247**	**2,812**	**3,450**	**4,267**	**4.5**
China	620	792	805	968	1,245	1,586	1,890	2,527	4.9
India	153	222	230	289	373	455	537	637	4.3
South Korea	61	102	113	121	159	201	247	298	4.1
Other Asia	232	311	326	367	470	570	675	804	3.8
Middle East	**229**	**269**	**283**	**352**	**435**	**521**	**616**	**729**	**4.0**
Turkey	35	40	43	48	64	75	87	102	3.7
Africa	**178**	**192**	**198**	**226**	**268**	**313**	**358**	**409**	**3.1**
Central and South America	**174**	**194**	**206**	**281**	**395**	**532**	**694**	**905**	**6.4**
Brazil	57	64	71	76	106	144	191	251	5.4
Other Central/South America	117	130	135	205	289	388	503	654	6.8
Total Developing	**1,646**	**2,083**	**2,161**	**2,605**	**3,344**	**4,178**	**5,118**	**6,311**	**4.6**
Total World	**5,786**	**5,842**	**5,980**	**6,677**	**7,839**	**9,041**	**10,381**	**11,996**	**2.9**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. The U.S. numbers include carbon emissions attributable to renewable energy sources.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table B19; and World Energy Projection System (1999).

Table B11. World Carbon Emissions from Oil Use by Region, High Economic Growth Case, 1990-2020
(Million Metric Tons)

Region/Country	History			Projections					Average Annual Percent Change, 1996-2020
	1990	1995	1996	2000	2005	2010	2015	2020	
Industrialized Countries									
North America	**714**	**721**	**747**	**814**	**880**	**961**	**1,026**	**1,101**	**1.6**
United States[a]	591	597	621	671	725	787	836	886	1.5
Canada	61	62	64	74	76	82	86	90	1.4
Mexico	62	61	62	69	79	92	107	125	2.9
Western Europe	**477**	**478**	**483**	**520**	**545**	**572**	**597**	**624**	**1.1**
United Kingdom	66	63	63	66	72	76	79	83	1.2
France	67	65	66	70	74	78	81	83	1.0
Germany	99	101	102	108	114	120	124	129	1.0
Italy	74	76	77	79	91	99	107	115	1.7
Netherlands	29	26	25	27	29	31	33	35	1.3
Other Western Europe	141	147	149	172	164	169	174	179	0.8
Industrialized Asia	**219**	**218**	**221**	**220**	**241**	**259**	**277**	**297**	**1.2**
Japan	179	174	179	176	189	203	217	231	1.1
Australasia	40	44	43	44	51	56	61	66	1.8
Total Industrialized	**1,410**	**1,417**	**1,451**	**1,555**	**1,666**	**1,792**	**1,903**	**2,022**	**1.4**
EE/FSU									
Former Soviet Union	335	174	165	174	191	214	240	268	2.1
Eastern Europe	69	47	48	59	65	71	76	81	2.2
Total EE/FSU	**403**	**220**	**212**	**234**	**256**	**285**	**316**	**349**	**2.1**
Developing Countries									
Developing Asia	**310**	**396**	**416**	**501**	**603**	**754**	**926**	**1,079**	**4.1**
China	98	106	113	151	173	233	306	348	4.8
India	45	56	59	71	104	127	154	187	4.9
South Korea	38	66	71	74	104	131	162	199	4.4
Other Asia	129	168	173	205	222	263	304	346	2.9
Middle East	**154**	**174**	**181**	**213**	**280**	**336**	**401**	**480**	**4.2**
Turkey	17	21	22	24	34	41	50	59	4.3
Africa	**84**	**84**	**87**	**102**	**121**	**148**	**177**	**212**	**3.8**
Central and South America	**128**	**135**	**138**	**184**	**261**	**325**	**398**	**495**	**5.5**
Brazil	46	49	51	54	69	90	117	151	4.7
Other Central/South America	82	85	87	130	192	234	282	343	5.9
Total Developing	**677**	**789**	**821**	**1,000**	**1,264**	**1,563**	**1,902**	**2,265**	**4.3**
Total World	**2,490**	**2,427**	**2,485**	**2,789**	**3,186**	**3,641**	**4,121**	**4,636**	**2.6**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table B19; and World Energy Projection System (1999).

Table B12. World Carbon Emissions from Natural Gas Use by Region, High Economic Growth Case, 1990-2020
(Million Metric Tons)

Region/Country	History 1990	History 1995	History 1996	Projections 2000	Projections 2005	Projections 2010	Projections 2015	Projections 2020	Average Annual Percent Change, 1996-2020
Industrialized Countries									
North America	**320**	**370**	**378**	**405**	**471**	**531**	**590**	**628**	**2.1**
United States[a]	273	314	319	333	385	436	485	511	2.0
Canada	34	41	44	49	55	59	65	73	2.2
Mexico	13	15	15	23	32	36	40	43	4.4
Western Europe	**139**	**172**	**193**	**226**	**271**	**312**	**363**	**422**	**3.3**
United Kingdom	32	40	47	60	69	79	89	101	3.2
France	15	17	20	23	27	33	39	49	3.8
Germany	31	43	47	55	65	77	91	105	3.4
Italy	24	27	29	34	35	38	42	45	1.9
Netherlands	19	21	23	26	28	30	33	35	1.8
Other Western Europe	18	24	27	29	46	55	70	86	5.0
Industrialized Asia	**41**	**48**	**51**	**50**	**79**	**77**	**89**	**98**	**2.8**
Japan	29	35	37	34	62	59	70	79	3.2
Australasia	12	13	13	17	17	18	19	20	1.6
Total Industrialized	**500**	**590**	**622**	**682**	**821**	**920**	**1,041**	**1,148**	**2.6**
EE/FSU									
Former Soviet Union	323	262	264	276	346	409	484	580	3.3
Eastern Europe	41	36	39	50	71	98	125	158	6.0
Total EE/FSU	**365**	**298**	**303**	**326**	**417**	**508**	**609**	**738**	**3.8**
Developing Countries									
Developing Asia	**40**	**69**	**79**	**98**	**199**	**288**	**412**	**552**	**8.5**
China	7	9	10	21	47	74	126	177	12.7
India	6	10	11	21	35	54	77	106	9.7
South Korea	2	6	8	8	11	15	22	30	5.9
Other Asia	26	45	50	49	106	145	188	240	6.8
Middle East	**55**	**73**	**80**	**112**	**126**	**152**	**180**	**211**	**4.1**
Turkey	2	3	4	4	8	9	11	15	5.7
Africa	**20**	**26**	**27**	**31**	**41**	**49**	**56**	**64**	**3.6**
Central and South America	**29**	**39**	**43**	**66**	**99**	**169**	**252**	**360**	**9.3**
Brazil	1	2	3	5	16	31	48	69	13.9
Other Central/South America	28	37	40	61	83	138	204	291	8.6
Total Developing	**145**	**208**	**229**	**307**	**465**	**657**	**900**	**1,187**	**7.1**
Total World	**1,009**	**1,096**	**1,153**	**1,315**	**1,703**	**2,086**	**2,550**	**3,073**	**4.2**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table B19; and World Energy Projection System (1999).

Table B13. World Carbon Emissions from Coal Use by Region, High Economic Growth Case, 1990-2020
(Million Metric Tons)

Region/Country	History			Projections					Average Annual Percent Change, 1996-2020
	1990	1995	1996	2000	2005	2010	2015	2020	
Industrialized Countries									
North America	516	538	560	626	652	678	723	778	1.4
United States[a]	481	500	521	587	611	634	674	725	1.4
Canada	31	32	32	32	33	33	37	41	1.0
Mexico	3	6	6	7	9	11	12	13	3.0
Western Europe	319	234	229	221	209	201	194	183	-0.9
United Kingdom	69	42	43	35	31	27	24	17	-3.9
France	20	15	15	12	9	5	5	4	-5.7
Germany	137	91	89	87	85	84	83	81	-0.4
Italy	15	12	10	12	12	12	12	12	0.4
Netherlands	11	10	10	10	10	10	9	9	-0.5
Other Western Europe	67	63	61	65	62	63	61	61	0.0
Industrialized Asia	105	113	117	116	138	142	148	152	1.1
Japan	66	72	74	72	92	95	99	102	1.3
Australasia	39	41	43	45	46	47	49	50	0.7
Total Industrialized	940	885	905	963	999	1,021	1,064	1,114	0.9
EE/FSU									
Former Soviet Union	333	201	185	165	177	185	187	184	0.0
Eastern Europe	189	148	142	147	158	150	142	129	-0.4
Total EE/FSU	522	348	327	313	335	335	329	313	-0.2
Developing Countries									
Developing Asia	714	962	980	1,146	1,445	1,770	2,112	2,636	4.2
China	514	677	682	796	1,025	1,280	1,558	2,003	4.6
India	101	156	160	196	234	274	307	345	3.2
South Korea	21	30	34	40	44	54	64	69	3.0
Other Asia	78	98	103	114	142	162	183	219	3.2
Middle East	20	21	23	27	30	33	36	38	2.2
Turkey	16	18	17	20	21	25	26	28	2.1
Africa	74	82	84	93	106	116	125	134	2.0
Central and South America	17	20	25	31	35	39	44	50	3.0
Brazil	9	12	17	18	21	23	26	30	2.5
Other Central/South America	7	8	8	14	14	16	17	20	3.8
Total Developing	825	1,086	1,111	1,298	1,615	1,957	2,316	2,859	4.0
Total World	2,287	2,319	2,343	2,573	2,949	3,314	3,709	4,285	2.5

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table B19; and World Energy Projection System (1999).

Table B14. World Nuclear Generating Capacity by Region and Country, High Nuclear Case, 1996-2020
(Megawatts)

Region/Country	History		Projections				
	1996	1997	2000	2005	2010	2015	2020
Industrialized							
North America							
United States	100,817	99,046	95,455	93,245	85,461	79,373	78,204
Canada	14,902	11,994	11,146	10,298	10,298	10,298	11,994
Mexico	1,308	1,308	1,308	1,308	1,308	1,308	1,308
Industrialized Asia							
Japan	42,369	43,850	43,691	45,267	54,834	58,434	65,823
Western Europe							
Belgium	5,712	5,712	5,712	5,712	5,712	5,712	5,712
Finland	2,355	2,560	2,815	2,815	3,815	3,815	3,370
France	59,948	62,853	63,103	63,103	64,320	67,220	71,570
Germany	22,282	22,282	22,282	22,282	21,942	20,135	14,294
Netherlands	504	449	449	449	449	449	449
Spain	7,207	7,415	7,415	7,415	7,262	6,822	6,822
Sweden	10,040	10,040	10,040	10,040	10,040	8,380	7,790
Switzerland	3,077	3,079	3,079	3,194	3,194	3,194	3,529
United Kingdom	12,928	12,968	12,968	12,968	12,568	12,087	11,852
Total Industrialized	**283,449**	**283,556**	**279,463**	**278,096**	**281,203**	**277,237**	**282,717**
EE/FSU							
Eastern Europe							
Bulgaria	3,538	3,538	3,538	3,538	3,538	3,538	3,130
Czech Republic	1,648	1,648	2,560	3,472	3,472	3,472	3,472
Hungary	1,729	1,729	1,729	1,729	1,729	1,729	1,729
Romania	650	650	650	1,300	1,950	1,950	1,950
Slovak Republic	1,632	1,632	2,456	2,048	2,048	2,048	1,232
Slovenia	632	632	632	632	632	632	632
Former Soviet Union							
Armenia	376	376	376	752	752	752	752
Belarus	0	0	0	0	0	1,000	2,000
Kazakhstan	70	70	70	70	670	1,200	1,800
Lithuania	2,370	2,370	2,370	2,370	2,370	2,370	2,370
Russia	19,843	19,843	22,668	23,618	24,601	28,799	33,305
Ukraine	13,765	13,765	13,065	13,090	14,990	16,390	17,790
Total EE/FSU	**46,253**	**46,253**	**50,114**	**52,619**	**56,752**	**63,880**	**70,162**

See notes at end of table.

Table B14. World Nuclear Generating Capacity by Region and Country, High Nuclear Case, 1996-2020 (Continued)
(Megawatts)

Region/Country	History		Projections				
	1996	1997	2000	2005	2010	2015	2020
Developing Countries							
Developing Asia							
China	2,167	2,167	2,167	6,737	11,542	17,162	24,562
India	1,695	1,695	2,301	3,103	7,463	8,913	10,813
Indonesia	0	0	0	0	0	0	1,800
Korea, North	0	0	0	950	1,900	1,900	1,900
Korea, South	9,120	8,770	12,990	14,890	16,790	19,640	21,934
Pakistan	125	125	425	425	725	600	600
Philippines	0	0	0	0	0	0	900
Taiwan	4,884	4,884	4,884	7,384	8,634	11,134	12,384
Thailand	0	0	0	0	0	0	1,000
Vietnam	0	0	0	0	0	1,000	1,000
Central and South America							
Argentina	935	935	935	1,627	1,627	1,292	1,292
Brazil	626	626	626	1,871	1,871	3,116	3,116
Cuba	0	0	0	0	408	816	816
Middle East							
Iran	0	0	0	1,073	2,146	2,146	2,146
Egypt	0	0	0	0	0	600	600
Turkey	0	0	0	0	1,300	2,600	2,600
Africa							
South Africa	1,842	1,842	1,842	1,842	1,842	1,842	1,842
Total Developing	**21,394**	**22,044**	**26,170**	**39,902**	**56,248**	**72,761**	**89,305**
Total World	**351,096**	**351,853**	**355,747**	**370,617**	**394,203**	**413,878**	**442,184**

Note: EE/FSU = Eastern Europe/Former Soviet Union.

Sources: **History:** International Atomic Energy Agency, *Nuclear Power Reactors in the World* (Vienna, Austria, April 1998). **Projections:** Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, based on detailed assessments of country-specific nuclear power plants.

Table B15. World Total Energy Consumption in Oil-Equivalent Units by Region, High Economic Growth Case, 1990-2020
(Million Tons Oil Equivalent)

Region/Country	History			Projections					Average Annual Percent Change, 1996-2020
	1990	1995	1996	2000	2005	2010	2015	2020	
Industrialized Countries									
North America	**2,513**	**2,723**	**2,811**	**3,029**	**3,297**	**3,560**	**3,801**	**4,048**	**1.5**
United States[a]	2,115	2,278	2,352	2,511	2,707	2,905	3,083	3,260	1.4
Canada	274	307	317	349	385	418	447	478	1.7
Mexico	124	138	142	169	206	237	272	310	3.3
Western Europe	**1,511**	**1,570**	**1,613**	**1,740**	**1,873**	**1,996**	**2,124**	**2,263**	**1.4**
United Kingdom	236	233	249	270	295	316	337	359	1.5
France	235	257	267	282	300	319	338	359	1.2
Germany	372	358	365	390	420	449	479	512	1.4
Italy	168	179	183	196	215	234	252	272	1.7
Netherlands	83	89	92	101	109	117	126	135	1.6
Other Western Europe	419	453	458	500	533	561	592	628	1.3
Industrialized Asia	**579**	**663**	**678**	**681**	**806**	**857**	**916**	**976**	**1.5**
Japan	456	523	539	529	641	682	731	776	1.5
Australasia	123	140	139	152	165	175	187	200	1.5
Total Industrialized	**4,604**	**4,955**	**5,103**	**5,449**	**5,976**	**6,414**	**6,843**	**7,287**	**1.5**
EE/FSU									
Former Soviet Union	1,473	1,027	1,003	1,022	1,200	1,368	1,561	1,780	2.4
Eastern Europe	382	312	316	359	426	488	552	625	2.9
Total EE/FSU	**1,855**	**1,340**	**1,319**	**1,381**	**1,626**	**1,856**	**2,113**	**2,405**	**2.5**
Developing Countries									
Developing Asia	**1,294**	**1,811**	**1,879**	**2,241**	**2,961**	**3,729**	**4,608**	**5,665**	**4.7**
China	680	917	935	1,142	1,510	1,941	2,455	3,084	5.1
India	195	279	291	376	497	618	752	915	4.9
South Korea	93	165	180	206	270	341	419	504	4.4
Other Asia	327	449	473	516	684	830	981	1,161	3.8
Middle East	**331**	**413**	**436**	**553**	**678**	**818**	**971**	**1,149**	**4.1**
Turkey	50	63	67	84	102	123	147	175	4.1
Africa	**233**	**270**	**279**	**321**	**386**	**454**	**522**	**600**	**3.2**
Central and South America	**346**	**423**	**446**	**592**	**792**	**1,044**	**1,343**	**1,728**	**5.8**
Brazil	136	161	173	186	244	317	405	516	4.7
Other Central/South America	210	262	274	406	548	727	938	1,212	6.4
Total Developing	**2,203**	**2,917**	**3,039**	**3,706**	**4,817**	**6,045**	**7,443**	**9,142**	**4.7**
Total World	**8,663**	**9,212**	**9,461**	**10,537**	**12,419**	**14,316**	**16,399**	**18,834**	**2.9**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table B1; and World Energy Projection System (1999).

Appendix C

Low Economic Growth Case Projections:

- World Energy Consumption
- Gross Domestic Product
- Carbon Emissions
- Nuclear Power Capacity

Table C1. World Total Energy Consumption by Region, Low Economic Growth Case, 1990-2020
(Quadrillion Btu)

Region/Country	History			Projections					Average Annual Percent Change, 1996-2020
	1990	1995	1996	2000	2005	2010	2015	2020	
Industrialized Countries									
North America	**99.7**	**108.0**	**111.6**	**118.3**	**123.0**	**128.4**	**132.0**	**134.9**	**0.8**
United States[a]	83.9	90.4	93.3	98.8	102.0	106.2	108.7	110.5	0.7
Canada	10.9	12.2	12.6	13.2	13.9	14.4	14.7	15.1	0.7
Mexico	4.9	5.5	5.6	6.3	7.2	7.9	8.6	9.3	2.1
Western Europe	**60.0**	**62.3**	**64.0**	**66.2**	**68.4**	**70.2**	**72.0**	**73.9**	**0.6**
United Kingdom	9.4	9.3	9.9	10.2	10.7	11.0	11.3	11.6	0.7
France	9.3	10.2	10.6	10.8	11.1	11.4	11.6	11.8	0.5
Germany	14.7	14.2	14.5	14.9	15.4	15.9	16.3	16.8	0.6
Italy	6.7	7.1	7.2	7.4	7.8	8.0	8.3	8.5	0.7
Netherlands	3.3	3.5	3.7	3.8	4.0	4.1	4.2	4.3	0.7
Other Western Europe	16.6	18.0	18.2	19.0	19.5	19.9	20.4	20.9	0.6
Industrialized Asia	**23.0**	**26.3**	**26.9**	**25.5**	**27.3**	**28.0**	**28.8**	**29.6**	**0.4**
Japan	18.1	20.8	21.4	19.8	21.4	21.9	22.6	23.2	0.3
Australasia	4.9	5.6	5.5	5.7	5.9	6.1	6.2	6.4	0.6
Total Industrialized	**182.7**	**196.6**	**202.5**	**210.1**	**218.7**	**226.7**	**232.9**	**238.3**	**0.7**
EE/FSU									
Former Soviet Union	58.5	40.8	39.8	37.4	39.1	40.5	41.9	43.4	0.4
Eastern Europe	15.2	12.4	12.6	13.2	14.2	15.0	15.6	16.2	1.1
Total EE/FSU	**73.6**	**53.2**	**52.4**	**50.6**	**53.4**	**55.5**	**57.5**	**59.6**	**0.5**
Developing Countries									
Developing Asia	**51.4**	**71.8**	**74.5**	**78.6**	**91.4**	**102.6**	**113.3**	**124.7**	**2.2**
China	27.0	36.4	37.1	40.1	46.2	51.8	57.3	63.1	2.2
India	7.7	11.1	11.5	13.3	15.6	17.6	19.6	21.8	2.7
South Korea	3.7	6.5	7.2	6.9	8.2	9.4	10.6	11.7	2.1
Other Asia	13.0	17.8	18.8	18.2	21.4	23.8	25.8	28.1	1.7
Middle East	**13.1**	**16.4**	**17.3**	**18.4**	**20.4**	**22.4**	**24.3**	**26.3**	**1.8**
Turkey	2.0	2.5	2.7	3.0	3.3	3.6	3.9	4.3	2.0
Africa	**9.2**	**10.7**	**11.1**	**11.3**	**12.4**	**13.4**	**14.1**	**15.0**	**1.3**
Central and South America	**13.7**	**16.8**	**17.7**	**18.7**	**22.0**	**25.5**	**29.0**	**32.9**	**2.6**
Brazil	5.4	6.4	6.8	6.7	7.8	8.9	10.0	11.3	2.1
Other Central/South America	8.3	10.4	10.9	11.9	14.2	16.6	19.0	21.7	2.9
Total Developing	**87.4**	**115.7**	**120.6**	**127.0**	**146.2**	**163.8**	**180.7**	**199.0**	**2.1**
Total World	**343.8**	**365.6**	**375.5**	**387.7**	**418.3**	**446.0**	**471.0**	**496.8**	**1.2**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Energy totals include net imports of coal coke and electricity generated from biomass in the United States. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country.

Sources: **History**: Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections**: EIA, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table C1; and World Energy Projection System (1999).

Table C2. World Total Energy Consumption by Region and Fuel, Low Economic Growth Case, 1990-2020
(Quadrillion Btu)

Region/Country	History			Projections					Average Annual Percent Change, 1996-2020
	1990	1995	1996	2000	2005	2010	2015	2020	
Industrialized Countries									
North America									
Oil	40.4	41.8	43.2	46.6	48.2	50.7	52.3	53.7	0.9
Natural Gas	22.7	26.2	26.8	27.9	30.4	32.9	35.3	36.8	1.3
Coal	20.4	21.1	22.0	24.2	24.4	25.0	25.7	26.2	0.7
Nuclear	7.0	8.3	8.2	8.0	7.5	6.7	5.2	4.3	-2.7
Other	9.2	10.6	11.4	11.6	12.5	13.2	13.5	13.9	0.8
Total	**99.7**	**108.0**	**111.6**	**118.3**	**123.0**	**128.4**	**132.0**	**134.9**	**0.8**
Western Europe									
Oil	25.8	28.0	28.2	29.2	29.3	29.6	29.8	30.0	0.3
Natural Gas	9.9	12.2	13.7	15.4	17.7	19.6	22.0	24.6	2.5
Coal	12.5	9.1	9.1	8.2	7.4	6.9	6.4	5.8	-1.8
Nuclear	7.4	8.2	8.6	8.7	8.5	8.1	7.4	6.6	-1.1
Other	4.4	4.8	4.5	4.7	5.5	6.0	6.5	6.9	1.8
Total	**60.0**	**62.3**	**64.0**	**66.2**	**68.4**	**70.2**	**72.0**	**73.9**	**0.6**
Industrialized Asia									
Oil	12.5	14.1	14.3	13.5	13.3	13.8	14.2	14.6	0.1
Natural Gas	2.9	3.3	3.6	3.3	4.7	4.5	4.9	5.3	1.6
Coal	4.2	4.6	4.7	4.4	4.8	4.8	4.8	4.8	0.0
Nuclear	2.0	2.8	2.9	3.0	2.9	3.4	3.3	3.2	0.4
Other	1.4	1.4	1.4	1.3	1.6	1.6	1.7	1.7	1.0
Total	**23.0**	**26.3**	**26.9**	**25.5**	**27.3**	**28.0**	**28.8**	**29.6**	**0.4**
Total Industrialized									
Oil	78.7	83.9	85.7	89.3	90.8	94.1	96.3	98.2	0.6
Natural Gas	35.5	41.8	44.0	46.7	52.8	57.0	62.2	66.7	1.8
Coal	37.2	34.8	35.8	36.8	36.6	36.6	36.9	36.7	0.1
Nuclear	16.3	19.4	19.8	19.7	18.9	18.2	15.8	14.1	-1.4
Other	15.0	16.8	17.2	17.5	19.6	20.8	21.7	22.6	1.1
Total	**182.7**	**196.6**	**202.5**	**210.1**	**218.7**	**226.7**	**232.9**	**238.3**	**0.7**
EE/FSU									
Oil	21.0	12.4	12.0	12.2	12.0	12.1	12.2	12.3	0.1
Natural Gas	26.0	21.4	21.7	21.6	24.7	27.4	29.9	33.0	1.8
Coal	20.8	13.8	13.0	11.5	11.1	10.1	9.0	7.8	-2.1
Nuclear	2.9	2.5	2.8	2.7	2.6	2.7	2.7	2.3	-0.8
Other	2.8	3.0	2.9	2.6	2.9	3.1	3.6	4.2	1.6
Total	**73.6**	**53.2**	**52.4**	**50.6**	**53.4**	**55.5**	**57.5**	**59.6**	**0.5**
Developing Countries									
Developing Asia									
Oil	16.0	23.6	24.8	26.4	27.9	31.1	34.2	35.7	1.5
Natural Gas	3.0	5.1	5.7	6.3	11.3	14.5	18.8	22.3	5.8
Coal	28.1	38.0	38.7	40.0	44.4	48.5	51.7	57.8	1.7
Nuclear	0.9	1.2	1.3	1.4	1.8	2.1	2.2	2.2	2.3
Other	3.2	4.0	4.0	4.5	6.0	6.3	6.5	6.7	2.2
Total	**51.4**	**71.8**	**74.5**	**78.6**	**91.4**	**102.6**	**113.3**	**124.7**	**2.2**

See notes at end of table.

Table C2. World Total Energy Consumption by Region and Fuel, Low Economic Growth Case, 1990-2020 (Continued)
(Quadrillion Btu)

Region/Country	History			Projections					Average Annual Percent Change, 1996-2020
	1990	1995	1996	2000	2005	2010	2015	2020	
Developing Countries (Continued)									
Middle East									
Oil	8.1	9.8	10.1	10.0	11.9	13.0	14.2	15.5	1.8
Natural Gas	3.9	5.2	5.7	6.7	6.8	7.5	8.1	8.7	1.8
Coal	0.8	0.8	0.9	0.9	0.9	0.9	0.9	0.9	-0.1
Nuclear	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	N/A
Other	0.4	0.5	0.6	0.8	0.8	0.9	1.0	1.1	2.8
Total	**13.1**	**16.4**	**17.3**	**18.4**	**20.4**	**22.4**	**24.3**	**26.3**	**1.8**
Africa									
Oil	4.2	4.8	5.0	5.2	5.6	6.3	6.9	7.7	1.8
Natural Gas	1.4	1.9	2.0	2.0	2.4	2.6	2.8	2.9	1.7
Coal	3.0	3.3	3.4	3.3	3.4	3.5	3.4	3.4	0.0
Nuclear	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	-1.1
Other	0.6	0.6	0.6	0.7	0.8	0.9	0.9	0.9	1.8
Total	**9.2**	**10.7**	**11.1**	**11.3**	**12.4**	**13.4**	**14.1**	**15.0**	**1.3**
Central and South America									
Oil	6.9	8.0	8.1	8.6	10.8	11.8	12.8	14.0	2.3
Natural Gas	2.1	2.9	3.1	3.8	5.0	7.5	9.9	12.5	6.0
Coal	0.7	0.8	1.0	1.0	1.0	1.0	0.9	1.0	-0.1
Nuclear	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	-0.2
Other	3.9	5.1	5.4	5.1	5.1	5.1	5.2	5.3	0.0
Total	**13.7**	**16.8**	**17.7**	**18.7**	**22.0**	**25.5**	**29.0**	**32.9**	**2.6**
Total Developing Countries									
Oil	35.2	46.2	48.1	50.3	56.2	62.2	68.0	72.9	1.7
Natural Gas	10.5	15.0	16.5	18.8	25.5	32.2	39.4	46.4	4.4
Coal	32.5	42.9	43.9	45.2	49.7	53.8	56.9	63.0	1.5
Nuclear	1.1	1.4	1.5	1.6	2.0	2.4	2.6	2.5	2.1
Other	8.1	10.2	10.6	11.1	12.7	13.2	13.7	14.1	1.2
Total	**87.4**	**115.7**	**120.6**	**127.0**	**146.2**	**163.8**	**180.7**	**199.0**	**2.1**
Total World									
Oil	134.9	142.5	145.7	151.7	158.9	168.5	176.5	183.4	1.0
Natural Gas	72.0	78.1	82.2	87.1	103.1	116.5	131.5	146.1	2.4
Coal	90.5	91.6	92.8	93.6	97.4	100.5	102.9	107.6	0.6
Nuclear	20.4	23.3	24.1	24.0	23.7	23.4	21.2	18.9	-1.0
Other	25.9	30.1	30.7	31.2	35.2	37.1	38.9	40.9	1.2
Total	**343.8**	**365.6**	**375.5**	**387.7**	**418.3**	**446.0**	**471.0**	**496.8**	**1.2**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Energy totals include net imports of coal coke and electricity generated from biomass in the United States. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table C1; and World Energy Projection System (1999).

Table C3. World Gross Domestic Product (GDP) by Region, Low Economic Growth Case, 1990-2020
(Billion 1997 Dollars)

Region/Country	History			Projections					Percent Change, 1996-2020	
	1990	1995	1996	2000	2005	2010	2015	2020	Annual Average	Total
Industrialized Countries										
North America	**7,726**	**8,492**	**8,778**	**9,483**	**10,195**	**11,026**	**11,562**	**12,017**	**1.3**	**36.9**
United States[a]	6,848	7,546	7,806	8,401	8,962	9,628	10,003	10,294	1.2	31.9
Canada	546	588	596	645	710	771	811	853	1.5	43.2
Mexico	332	358	377	437	523	627	739	870	3.8	131.0
Western Europe	**7,595**	**8,118**	**8,258**	**8,705**	**9,496**	**10,181**	**10,879**	**11,627**	**1.4**	**40.8**
United Kingdom	1,143	1,219	1,246	1,319	1,449	1,557	1,665	1,780	1.5	42.9
France	1,269	1,340	1,361	1,439	1,527	1,627	1,719	1,815	1.2	33.4
Germany	1,839	2,019	2,045	2,156	2,347	2,529	2,719	2,923	1.5	42.9
Italy	1,060	1,121	1,128	1,181	1,278	1,369	1,464	1,565	1.4	38.7
Netherlands	303	336	347	379	408	436	466	497	1.5	43.3
Other Western Europe	1,951	2,083	2,132	2,310	2,486	2,661	2,847	3,048	1.5	43.0
Industrialized Asia	**4,094**	**4,424**	**4,602**	**4,213**	**4,486**	**4,833**	**5,192**	**5,577**	**0.8**	**21.2**
Japan	3,720	3,994	4,158	3,740	3,983	4,297	4,621	4,968	0.7	19.5
Australasia	374	429	444	472	505	536	571	609	1.3	37.1
Total Industrialized	**19,384**	**21,034**	**21,638**	**22,480**	**24,179**	**26,040**	**27,623**	**29,221**	**1.3**	**35.0**
EE/FSU										
Former Soviet Union	1,049	621	594	516	563	608	657	710	0.8	19.7
Eastern Europe	356	333	347	387	462	528	586	649	2.6	87.2
Total EE/FSU	**1,404**	**954**	**940**	**903**	**1,025**	**1,137**	**1,243**	**1,360**	**1.5**	**44.6**
Developing Countries										
Developing Asia	**1,726**	**2,536**	**2,727**	**2,844**	**3,497**	**4,191**	**4,916**	**5,774**	**3.2**	**111.7**
China	440	777	851	953	1,185	1,419	1,667	1,958	3.5	130.0
India	278	345	370	427	513	613	731	872	3.6	135.6
South Korea	273	392	419	409	517	639	772	934	3.4	122.7
Other Asia	734	1,023	1,087	1,055	1,282	1,520	1,748	2,011	2.6	85.1
Middle East	**378**	**460**	**487**	**508**	**586**	**678**	**772**	**878**	**2.5**	**80.3**
Turkey	143	167	179	204	233	268	308	355	2.9	98.4
Africa	**244**	**258**	**267**	**274**	**314**	**355**	**395**	**439**	**2.1**	**64.3**
Central and South America	**1,116**	**1,349**	**1,392**	**1,429**	**1,710**	**2,027**	**2,350**	**2,726**	**2.8**	**95.8**
Brazil	660	756	778	761	890	1,039	1,192	1,368	2.4	75.9
Other Central/South America	457	593	614	669	820	988	1,158	1,358	3.4	121.1
Total Developing	**3,465**	**4,603**	**4,873**	**5,055**	**6,109**	**7,251**	**8,435**	**9,817**	**3.0**	**101.4**
Total World	**24,253**	**26,592**	**27,452**	**28,439**	**31,313**	**34,428**	**37,301**	**40,398**	**1.6**	**47.2**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding.

Sources: **History:** The WEFA Group, *World Economic Outlook: 20-Year Extension* (Eddystone, PA, April 1997). **Projections:** Standard & Poor's DRI, *World Economic Outlook*, Vol. 1 (Lexington, MA, 3rd Quarter 1998); Energy Information Administration (EIA), *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table C20; and EIA, World Energy Projection System (1999).

Table C4. World Oil Consumption by Region, Low Economic Growth Case, 1990-2020
(Million Barrels per Day)

Region/Country	History 1990	History 1995	History 1996	Projections 2000	Projections 2005	Projections 2010	Projections 2015	Projections 2020	Average Annual Percent Change, 1996-2020
Industrialized Countries									
North America	**20.4**	**21.3**	**22.0**	**23.8**	**24.7**	**26.0**	**26.7**	**27.4**	**0.9**
United States[a]	17.0	17.7	18.3	19.9	20.6	21.6	22.1	22.5	0.9
Canada	1.7	1.8	1.8	2.0	1.9	2.0	2.0	2.0	0.5
Mexico	1.7	1.9	1.9	2.0	2.1	2.3	2.6	2.9	1.8
Western Europe	**12.5**	**13.5**	**13.7**	**14.1**	**14.2**	**14.4**	**14.4**	**14.5**	**0.3**
United Kingdom	1.8	1.8	1.8	1.8	1.9	2.0	2.0	2.0	0.3
France	1.8	1.9	1.9	2.0	2.0	2.0	2.0	2.0	0.2
Germany	2.7	2.9	2.9	3.0	3.0	3.0	3.0	3.0	0.2
Italy	1.9	2.0	2.1	2.0	2.2	2.3	2.4	2.4	0.7
Netherlands	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.4
Other Western Europe	3.6	4.1	4.1	4.6	4.2	4.2	4.2	4.2	0.0
Industrialized Asia	**6.2**	**7.0**	**7.1**	**6.7**	**6.5**	**6.8**	**7.0**	**7.2**	**0.1**
Japan	5.1	5.7	5.9	5.5	5.2	5.4	5.6	5.7	-0.1
Australasia	1.0	1.2	1.2	1.2	1.3	1.4	1.4	1.5	0.9
Total Industrialized	**39.0**	**41.8**	**42.7**	**44.6**	**45.4**	**47.1**	**48.2**	**49.2**	**0.6**
EE/FSU									
Former Soviet Union	8.4	4.6	4.4	4.3	4.2	4.3	4.3	4.4	0.0
Eastern Europe	1.6	1.3	1.3	1.5	1.5	1.5	1.5	1.5	0.4
Total EE/FSU	**10.0**	**5.9**	**5.7**	**5.8**	**5.7**	**5.8**	**5.8**	**5.9**	**0.1**
Developing Countries									
Developing Asia	**7.6**	**11.3**	**11.9**	**12.6**	**13.5**	**15.1**	**16.7**	**17.7**	**1.7**
China	2.3	3.3	3.5	4.2	4.2	4.9	5.6	5.8	1.9
India	1.2	1.6	1.7	1.8	2.3	2.6	2.9	3.2	2.7
South Korea	1.0	2.0	2.2	1.9	2.4	2.8	3.1	3.6	2.1
Other Asia	3.1	4.3	4.5	4.7	4.5	4.9	5.1	5.3	0.7
Middle East	**3.9**	**4.7**	**4.8**	**4.8**	**5.7**	**6.2**	**6.8**	**7.4**	**1.8**
Turkey	0.5	0.6	0.6	0.6	0.8	0.9	1.0	1.1	2.2
Africa	**2.1**	**2.3**	**2.4**	**2.5**	**2.7**	**3.0**	**3.3**	**3.7**	**1.8**
Central and South America	**3.4**	**3.9**	**4.0**	**4.2**	**5.3**	**5.8**	**6.3**	**6.9**	**2.3**
Brazil	1.3	1.5	1.5	1.5	1.7	1.9	2.2	2.5	2.1
Other Central/South America	2.1	2.4	2.5	2.8	3.6	3.9	4.1	4.4	2.4
Total Developing	**17.0**	**22.2**	**23.1**	**24.2**	**27.2**	**30.2**	**33.1**	**35.7**	**1.8**
Total World	**66.0**	**69.9**	**71.5**	**74.6**	**78.3**	**83.1**	**87.1**	**90.7**	**1.0**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table C21; and World Energy Projection System (1999).

Table C5. World Natural Gas Consumption by Region, Low Economic Growth Case, 1990-2020
(Trillion Cubic Feet)

Region/Country	History			Projections					Average Annual Percent Change, 1996-2020
	1990	1995	1996	2000	2005	2010	2015	2020	
Industrialized Countries									
North America	**22.0**	**25.4**	**26.0**	**27.1**	**29.5**	**31.9**	**34.3**	**35.8**	**1.3**
United States[a]	18.7	21.6	21.9	22.4	24.2	26.3	28.4	29.5	1.2
Canada	2.4	2.9	3.1	3.3	3.5	3.6	3.8	4.1	1.2
Mexico	0.9	1.0	1.0	1.4	1.8	2.0	2.1	2.2	3.2
Western Europe	**10.1**	**12.4**	**13.8**	**15.5**	**17.8**	**19.8**	**22.2**	**24.8**	**2.5**
United Kingdom	2.1	2.7	3.2	3.8	4.2	4.7	5.0	5.5	2.3
France	1.0	1.2	1.3	1.5	1.7	2.0	2.2	2.7	3.0
Germany	2.7	3.4	3.7	4.1	4.7	5.4	6.2	6.8	2.6
Italy	1.7	1.9	2.0	2.2	2.2	2.3	2.4	2.5	0.9
Netherlands	1.5	1.7	1.9	2.0	2.1	2.1	2.2	2.3	0.9
Other Western Europe	1.2	1.6	1.8	1.8	2.8	3.3	4.0	4.8	4.2
Industrialized Asia	**2.6**	**3.1**	**3.3**	**3.1**	**4.3**	**4.1**	**4.5**	**4.8**	**1.6**
Japan	1.9	2.2	2.4	2.0	3.3	3.1	3.5	3.8	1.9
Australasia	0.8	0.9	0.9	1.1	1.0	1.0	1.0	1.0	0.7
Total Industrialized	**34.8**	**41.0**	**43.1**	**45.7**	**51.7**	**55.8**	**61.0**	**65.4**	**1.8**
EE/FSU									
Former Soviet Union	25.0	20.6	20.7	20.0	22.4	24.0	25.8	28.0	1.3
Eastern Europe	3.1	2.7	2.9	3.4	4.5	5.7	6.7	7.7	4.1
Total EE/FSU	**28.1**	**23.4**	**23.7**	**23.5**	**26.9**	**29.7**	**32.4**	**35.7**	**1.7**
Developing Countries									
Developing Asia	**3.0**	**4.7**	**5.3**	**5.8**	**10.5**	**13.7**	**17.5**	**21.1**	**5.9**
China	0.5	0.6	0.7	1.2	2.4	3.3	4.9	6.1	9.7
India	0.4	0.6	0.7	1.2	1.7	2.4	3.1	3.9	7.4
South Korea	0.1	0.3	0.5	0.6	0.7	0.9	1.2	1.5	5.0
Other Asia	1.9	3.2	3.5	2.9	5.7	7.1	8.3	9.7	4.3
Middle East	**3.7**	**5.0**	**5.4**	**6.4**	**6.5**	**7.1**	**7.7**	**8.3**	**1.8**
Turkey	0.1	0.2	0.3	0.5	0.5	0.6	0.7	0.9	4.9
Africa	**1.4**	**1.7**	**1.8**	**1.8**	**2.2**	**2.4**	**2.5**	**2.6**	**1.7**
Central and South America	**2.0**	**2.6**	**2.9**	**3.5**	**4.7**	**7.0**	**9.2**	**11.6**	**6.0**
Brazil	0.1	0.2	0.2	0.3	0.9	1.5	2.0	2.6	11.1
Other Central/South America	1.9	2.4	2.7	3.2	3.8	5.5	7.2	9.1	5.2
Total Developing	**10.1**	**14.0**	**15.4**	**17.6**	**23.8**	**30.2**	**36.9**	**43.7**	**4.4**
Total World	**73.0**	**78.3**	**82.2**	**86.7**	**102.4**	**115.7**	**130.3**	**144.8**	**2.4**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country. To convert cubic feet to cubic meters, divide each number in the table by 35.315.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table C13; and World Energy Projection System (1999).

Table C6. World Coal Consumption by Region, Low Economic Growth Case, 1990-2020
(Million Short Tons)

Region/Country	History			Projections					Average Annual Percent Change, 1996-2020
	1990	1995	1996	2000	2005	2010	2015	2020	
Industrialized Countries									
North America	957	1,013	1,056	1,160	1,173	1,202	1,249	1,276	0.8
United States[a]	896	941	983	1,088	1,101	1,128	1,172	1,195	0.8
Canada	55	59	60	57	55	53	56	60	0.0
Mexico	7	13	14	15	18	21	21	21	1.8
Western Europe	898	607	600	544	493	457	425	386	-1.8
United Kingdom	121	79	81	62	53	44	37	25	-4.7
France	36	26	26	20	13	8	7	5	-6.4
Germany	528	298	290	272	255	244	232	219	-1.2
Italy	25	20	19	19	19	16	17	16	-0.6
Netherlands	15	15	15	14	13	13	12	10	-1.4
Other Western Europe	173	170	170	165	152	149	141	135	-1.0
Industrialized Asia	233	257	265	252	268	267	265	264	0.0
Japan	125	140	144	131	149	150	150	149	0.1
Australasia	108	117	121	121	119	117	116	115	-0.2
Total Industrialized	2,088	1,876	1,922	1,956	1,934	1,925	1,940	1,926	0.0
EE/FSU									
Former Soviet Union	848	508	472	389	370	352	322	288	-2.0
Eastern Europe	523	426	413	398	389	339	294	245	-2.1
Total EE/FSU	1,372	934	885	786	759	691	617	533	-2.1
Developing Countries									
Developing Asia	1,555	2,030	2,085	2,131	2,352	2,544	2,687	2,974	1.5
China	1,124	1,489	1,500	1,550	1,739	1,893	2,015	2,272	1.7
India	242	312	321	350	370	393	403	415	1.1
South Korea	42	51	58	57	57	64	68	69	0.7
Other Asia	148	178	186	173	187	194	201	218	0.7
Middle East	66	76	80	82	80	80	81	79	-0.1
Turkey	60	67	72	75	72	76	75	73	0.1
Africa	152	172	174	173	178	179	177	176	0.0
Central and South America	30	32	40	40	39	39	38	39	-0.1
Brazil	17	19	27	26	27	26	26	27	0.0
Other Central/South America	13	13	13	14	12	12	12	12	-0.4
Total Developing	1,803	2,310	2,360	2,426	2,649	2,841	2,983	3,268	1.4
Total World	5,263	5,120	5,167	5,167	5,342	5,458	5,539	5,727	0.4

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country. To convert short tons to metric tons, divide each number in the table by 1.102.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table C16; and World Energy Projection System (1999).

Table C7. World Nuclear Energy Consumption by Region, Low Economic Growth Case, 1990-2020
(Billion Kilowatthours)

Region/Country	History			Projections					Average Annual Percent Change, 1996-2020
	1990	1995	1996	2000	2005	2010	2015	2020	
Industrialized Countries									
North America	649	774	770	744	703	625	483	399	-2.7
United States[a]	577	673	675	659	627	551	411	342	-2.8
Canada	69	93	88	77	68	67	65	50	-2.4
Mexico	3	8	7	8	8	7	7	7	-0.3
Western Europe	703	785	824	832	810	773	701	629	-1.1
United Kingdom	59	77	82	80	78	74	70	63	-1.1
France	298	358	376	393	387	387	382	360	-0.2
Germany	145	146	154	156	145	124	98	96	-1.9
Italy	0	0	0	0	0	0	0	0	0.0
Netherlands	3	4	4	3	3	3	0	0	-100.0
Other Western Europe	198	200	208	202	199	187	153	112	-2.6
Industrialized Asia	192	277	283	290	280	331	321	310	0.4
Japan	192	277	283	290	280	331	321	310	0.4
Australasia	0	0	0	0	0	0	0	0	0.0
Total Industrialized	1,544	1,837	1,877	1,867	1,792	1,729	1,504	1,338	-1.4
EE/FSU									
Former Soviet Union	201	172	194	190	182	183	187	154	-1.0
Eastern Europe	54	57	60	59	69	64	61	53	-0.5
Total EE/FSU	256	229	254	248	250	247	247	207	-0.8
Developing Countries									
Developing Asia	88	117	128	138	178	210	226	222	2.3
China	0	12	14	12	32	51	59	68	6.9
India	6	6	7	9	12	19	27	33	6.4
South Korea	50	64	70	85	87	89	92	81	0.6
Other Asia	32	34	37	33	47	50	49	40	0.4
Middle East	0	0	0	0	0	8	13	13	0.0
Turkey	0	0	0	0	0	0	5	5	0.0
Africa	8	11	12	11	10	10	9	9	-1.1
Central and South America	9	9	9	9	13	13	13	9	-0.2
Brazil	2	2	2	3	7	7	7	6	4.4
Other Central/South America	7	7	7	6	5	6	6	2	-4.6
Total Developing	105	138	149	157	201	241	261	252	2.2
Total World	1,905	2,203	2,280	2,273	2,244	2,217	2,013	1,797	-1.0

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table C8; and World Energy Projection System (1999).

Table C8. World Consumption of Hydroelectricity and Other Renewable Energy by Region, Low Economic Growth Case, 1990-2020
(Quadrillion Btu)

Region/Country	History 1990	History 1995	History 1996	Projections 2000	Projections 2005	Projections 2010	Projections 2015	Projections 2020	Average Annual Percent Change, 1996-2020
Industrialized Countries									
North America	9.2	10.6	11.4	11.6	12.5	13.2	13.5	13.9	0.8
United States[a]	5.8	6.8	7.3	7.2	7.4	7.6	7.8	8.0	0.4
Canada	3.1	3.4	3.6	3.9	4.5	4.9	5.0	5.1	1.4
Mexico	0.3	0.4	0.4	0.5	0.6	0.7	0.7	0.8	2.6
Western Europe	4.4	4.8	4.5	4.7	5.5	6.0	6.5	6.9	1.8
United Kingdom	0.1	0.1	0.0	0.1	0.2	0.3	0.3	0.4	9.6
France	0.6	0.7	0.7	0.7	0.8	0.9	0.9	0.9	1.4
Germany	0.2	0.2	0.2	0.3	0.5	0.6	0.8	0.8	5.9
Italy	0.4	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.5
Netherlands	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	18.3
Other Western Europe	3.2	3.3	3.1	3.0	3.5	3.6	3.7	3.9	1.1
Industrialized Asia	1.4	1.4	1.4	1.3	1.6	1.6	1.7	1.7	1.0
Japan	1.0	0.9	0.9	0.7	1.1	1.0	1.0	1.1	0.8
Australasia	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.7	1.5
Total Industrialized	15.0	16.8	17.2	17.5	19.6	20.8	21.7	22.6	1.1
EE/FSU									
Former Soviet Union	2.4	2.5	2.2	2.0	2.2	2.2	2.3	2.5	0.4
Eastern Europe	0.4	0.6	0.6	0.6	0.7	0.9	1.3	1.7	4.2
Total EE/FSU	2.8	3.0	2.9	2.6	2.9	3.1	3.6	4.2	1.6
Developing Countries									
Developing Asia	3.2	4.0	4.0	4.5	6.0	6.3	6.6	6.8	2.2
China	1.3	1.9	1.9	2.1	3.2	3.3	3.0	2.9	1.8
India	0.7	0.7	0.7	1.1	1.2	1.4	1.7	2.0	4.2
South Korea	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	5.1
Other Asia	1.1	1.3	1.3	1.2	1.5	1.6	1.7	1.8	1.2
Middle East	0.4	0.5	0.6	0.8	0.8	0.9	1.0	1.1	2.8
Turkey	0.2	0.4	0.4	0.5	0.4	0.5	0.5	0.5	0.5
Africa	0.6	0.6	0.6	0.7	0.8	0.9	0.9	0.9	1.9
Central and South America	3.9	5.1	5.4	5.1	5.1	5.1	5.2	5.3	0.0
Brazil	2.2	2.7	2.8	2.7	2.6	2.6	2.5	2.4	-0.6
Other Central/South America	1.7	2.4	2.6	2.4	2.4	2.5	2.7	2.9	0.5
Total Developing	8.1	10.2	10.6	11.1	12.7	13.2	13.7	14.2	1.2
Total World	25.9	30.1	30.7	31.2	35.2	37.1	39.0	41.0	1.2

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country. U.S. totals include net electricity imports, methanol, and liquid hydrogen.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table C1; and World Energy Projection System (1999).

Table C9. World Electricity Consumption by Region, Low Economic Growth Case, 1990-2020
(Billion Kilowatthours)

Region/Country	History			Projections					Average Annual Percent Change, 1996-2020
	1990	1995	1996	2000	2005	2010	2015	2020	
Industrialized Countries									
North America	**3,255**	**3,759**	**3,859**	**3,974**	**4,201**	**4,455**	**4,704**	**4,910**	**1.0**
United States[a]	2,713	3,163	3,243	3,321	3,495	3,688	3,875	4,013	0.9
Canada	435	462	473	494	511	538	561	586	0.9
Mexico	107	134	144	160	195	229	267	310	3.3
Western Europe	**2,064**	**2,209**	**2,245**	**2,331**	**2,528**	**2,725**	**2,934**	**3,151**	**1.4**
United Kingdom	286	301	305	311	335	357	379	401	1.1
France	324	365	378	396	425	457	490	520	1.3
Germany	485	473	473	474	518	564	613	661	1.4
Italy	222	247	248	272	304	338	375	414	2.2
Netherlands	71	82	85	92	100	109	119	129	1.8
Other Western Europe	675	742	756	787	844	899	959	1,026	1.3
Industrialized Asia	**930**	**1,068**	**1,090**	**1,114**	**1,233**	**1,304**	**1,376**	**1,445**	**1.2**
Japan	750	864	882	868	965	1,014	1,063	1,110	1.0
Australasia	180	204	207	246	268	290	314	335	2.0
Total Industrialized	**6,248**	**7,037**	**7,194**	**7,419**	**7,961**	**8,484**	**9,014**	**9,505**	**1.2**
EE/FSU									
Former Soviet Union	1,488	1,168	1,133	973	1,019	1,055	1,092	1,130	0.0
Eastern Europe	420	384	401	386	423	467	507	550	1.3
Total EE/FSU	**1,908**	**1,552**	**1,535**	**1,359**	**1,442**	**1,522**	**1,599**	**1,680**	**0.4**
Developing Countries									
Developing Asia	**1,268**	**1,912**	**2,002**	**2,189**	**2,681**	**3,168**	**3,689**	**4,279**	**3.2**
China	551	881	925	1,020	1,277	1,557	1,872	2,238	3.8
India	257	367	378	466	572	678	794	922	3.8
South Korea	95	162	181	174	207	237	267	296	2.1
Other Asia	365	501	519	528	625	696	757	823	1.9
Middle East	**272**	**371**	**386**	**403**	**457**	**513**	**570**	**626**	**2.0**
Turkey	51	76	85	122	161	225	268	355	6.1
Africa	**285**	**320**	**332**	**349**	**408**	**468**	**526**	**592**	**2.4**
Central and South America	**449**	**575**	**604**	**654**	**792**	**925**	**1,044**	**1,193**	**2.9**
Brazil	229	288	303	320	394	481	579	695	3.5
Other Central/South America	220	286	301	334	398	444	466	498	2.1
Total Developing	**2,274**	**3,178**	**3,324**	**3,595**	**4,338**	**5,075**	**5,829**	**6,690**	**3.0**
Total World	**10,431**	**11,767**	**12,053**	**12,373**	**13,741**	**15,080**	**16,442**	**17,875**	**1.7**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Electricity consumption equals generation plus imports minus exports minus distribution losses.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998), Table 6.2. **Projections:** EIA, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table C8; and World Energy Projection System (1999).

Table C10. World Carbon Emissions by Region, Low Economic Growth Case, 1990-2020
(Million Metric Tons)

Region/Country	History			Projections					Average Annual Percent Change, 1996-2020
	1990	1995	1996	2000	2005	2010	2015	2020	
Industrialized Countries									
North America	**1,550**	**1,629**	**1,685**	**1,819**	**1,890**	**1,965**	**2,066**	**2,125**	**1.0**
United States[a]	1,346	1,412	1,461	1,578	1,636	1,718	1,785	1,826	0.9
Canada	126	135	140	148	148	151	156	162	0.6
Mexico	78	82	84	94	106	116	126	137	2.1
Western Europe	**936**	**885**	**904**	**927**	**943**	**961**	**984**	**1,009**	**0.5**
United Kingdom	167	145	153	153	157	159	162	163	0.3
France	103	87	101	101	103	104	107	113	0.4
Germany	267	235	238	240	244	250	256	260	0.4
Italy	113	116	116	119	125	129	132	136	0.7
Netherlands	59	57	58	61	62	63	63	64	0.4
Other Western Europe	226	234	237	254	251	257	264	273	0.6
Industrialized Asia	**364**	**379**	**389**	**368**	**392**	**395**	**406**	**419**	**0.3**
Japan	274	281	291	266	288	290	300	310	0.3
Australasia	90	99	99	101	104	106	107	109	0.4
Total Industrialized	**2,850**	**2,893**	**2,978**	**3,113**	**3,224**	**3,341**	**3,459**	**3,554**	**0.7**
EE/FSU									
Former Soviet Union	991	636	613	568	587	603	616	633	0.1
Eastern Europe	299	230	228	237	247	248	244	241	0.2
Total EE/FSU	**1,290**	**866**	**842**	**805**	**834**	**851**	**860**	**874**	**0.2**
Developing Countries									
Developing Asia	**1,065**	**1,427**	**1,474**	**1,543**	**1,748**	**1,949**	**2,137**	**2,368**	**2.0**
China	620	792	805	857	960	1,087	1,170	1,304	2.0
India	153	222	230	258	294	326	352	382	2.1
South Korea	61	102	113	104	122	141	159	176	1.9
Other Asia	232	311	326	324	371	416	456	505	1.8
Middle East	**229**	**269**	**283**	**296**	**330**	**360**	**389**	**421**	**1.7**
Turkey	35	40	43	44	52	56	60	64	1.7
Africa	**178**	**192**	**198**	**201**	**216**	**232**	**244**	**258**	**1.1**
Central and South America	**174**	**194**	**206**	**224**	**276**	**327**	**377**	**434**	**3.2**
Brazil	57	64	71	70	85	102	119	138	2.8
Other Central/South America	117	130	135	154	191	226	258	296	3.3
Total Developing	**1,646**	**2,083**	**2,161**	**2,264**	**2,570**	**2,868**	**3,147**	**3,481**	**2.0**
Total World	**5,786**	**5,842**	**5,980**	**6,182**	**6,629**	**7,060**	**7,466**	**7,909**	**1.2**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. The U.S. numbers include carbon emissions attributable to renewable energy sources.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table C19; and World Energy Projection System (1999).

Table C11. World Carbon Emissions from Oil Use by Region, Low Economic Growth Case, 1990-2020
(Million Metric Tons)

Region/Country	History			Projections					Average Annual Percent Change, 1996-2020
	1990	1995	1996	2000	2005	2010	2015	2020	
Industrialized Countries									
North America	714	721	747	802	830	875	901	927	0.9
United States[a]	591	597	621	667	691	727	745	760	0.8
Canada	61	62	64	70	69	71	71	72	0.5
Mexico	62	61	62	65	70	77	85	95	1.8
Western Europe	477	478	483	499	501	506	509	512	0.2
United Kingdom	66	63	63	62	66	66	67	67	0.3
France	57	65	66	67	69	70	70	69	0.2
Germany	99	101	102	104	106	106	107	106	0.2
Italy	74	76	77	76	83	85	88	91	0.7
Netherlands	29	26	25	25	27	27	28	28	0.4
Other Western Europe	141	147	149	164	151	151	151	150	0.0
Industrialized Asia	219	218	221	208	205	213	220	227	0.1
Japan	179	174	179	166	159	165	169	174	-0.1
Australasia	40	44	43	42	47	49	51	53	0.9
Total Industrialized	1,410	1,417	1,451	1,510	1,537	1,594	1,630	1,665	0.6
EE/FSU									
Former Soviet Union	335	174	165	161	157	160	162	165	0.0
Eastern Europe	69	47	48	55	54	55	54	53	0.5
Total EE/FSU	403	220	212	216	212	215	217	218	0.1
Developing Countries									
Developing Asia	310	396	416	443	469	523	574	599	1.5
China	98	106	113	134	134	157	180	179	1.9
India	45	56	59	63	82	91	101	112	2.7
South Korea	38	66	71	62	80	91	103	117	2.1
Other Asia	129	168	173	183	174	184	190	191	0.4
Middle East	154	174	181	179	212	232	253	277	1.8
Turkey	17	21	22	22	28	31	34	37	2.2
Africa	84	84	87	91	98	110	121	133	1.8
Central and South America	128	135	138	146	182	200	217	237	2.3
Brazil	46	49	51	49	55	64	73	83	2.1
Other Central/South America	82	85	87	97	127	136	144	154	2.4
Total Developing	677	789	821	859	961	1,065	1,163	1,246	1.8
Total World	2,490	2,427	2,485	2,584	2,710	2,874	3,010	3,129	1.0

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table C19; and World Energy Projection System (1999).

Table C12. World Carbon Emissions from Natural Gas Use by Region, Low Economic Growth Case, 1990-2020
(Million Metric Tons)

Region/Country	History			Projections					Average Annual Percent Change, 1996-2020
	1990	1995	1996	2000	2005	2010	2015	2020	
Industrialized Countries									
North America	320	370	378	397	433	468	504	525	1.4
United States[a]	273	314	319	329	356	387	418	434	1.3
Canada	34	41	44	47	50	51	54	58	1.2
Mexico	13	16	15	22	28	30	32	33	3.2
Western Europe	139	172	193	217	249	276	309	346	2.5
United Kingdom	32	40	47	57	63	69	75	82	2.3
France	15	17	20	22	26	29	33	40	3.0
Germany	31	43	47	53	60	69	78	87	2.6
Italy	24	27	29	32	31	33	34	36	0.9
Netherlands	19	21	23	25	26	26	28	29	0.9
Other Western Europe	18	24	27	28	43	49	60	72	4.2
Industrialized Asia	41	48	51	48	67	64	70	75	1.6
Japan	29	35	37	32	52	48	54	59	1.9
Australasia	12	13	13	16	16	16	16	16	0.7
Total Industrialized	500	590	622	662	750	808	883	946	1.8
EE/FSU									
Former Soviet Union	323	262	264	255	285	305	327	356	1.3
Eastern Europe	41	36	39	46	60	76	89	103	4.1
Total EE/FSU	365	298	303	300	344	382	416	459	1.8
Developing Countries									
Developing Asia	40	69	79	87	155	199	255	306	5.8
China	7	9	10	18	36	50	74	91	9.7
India	6	10	11	19	28	38	50	63	7.4
South Korea	2	6	8	8	9	12	15	19	3.9
Other Asia	26	45	50	42	82	100	116	133	4.2
Middle East	55	73	80	94	95	105	113	122	1.8
Turkey	2	3	4	4	7	7	8	10	4.0
Africa	20	26	27	27	33	35	36	40	1.7
Central and South America	29	39	43	53	69	104	137	173	6.0
Brazil	1	2	3	4	13	22	30	38	11.1
Other Central/South America	28	37	40	48	56	82	107	135	5.2
Total Developing	145	208	229	261	353	444	544	641	4.4
Total World	1,009	1,096	1,153	1,223	1,447	1,634	1,843	2,047	2.4

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table C18; and World Energy Projection System (1999).

Table C13. World Carbon Emissions from Coal Use by Region, Low Economic Growth Case, 1990-2020
(Million Metric Tons)

Region/Country	History			Projections					Average Annual Percent Change, 1996-2020
	1990	1995	1996	2000	2005	2010	2015	2020	
Industrialized Countries									
North America	516	538	560	619	625	641	661	672	0.8
United States[a]	481	500	521	582	588	603	621	630	0.8
Canada	31	32	32	31	30	29	30	32	0.0
Mexico	3	6	6	6	8	9	9	9	1.8
Western Europe	319	234	229	212	192	178	166	151	-1.7
United Kingdom	69	42	43	33	26	23	20	14	-4.7
France	20	15	15	12	8	5	4	3	-6.4
Germany	137	91	89	83	78	75	71	67	-1.2
Italy	15	12	10	11	11	10	10	9	-0.6
Netherlands	11	10	10	10	9	9	8	7	-1.3
Other Western Europe	67	63	61	62	57	56	53	51	-0.7
Industrialized Asia	105	113	117	110	119	118	118	117	0.0
Japan	66	72	74	68	77	77	77	77	0.1
Australasia	39	41	43	43	42	41	41	40	-0.2
Total Industrialized	940	885	905	941	936	937	945	940	0.2
EE/FSU									
Former Soviet Union	333	201	185	152	145	138	126	113	-2.0
Eastern Europe	189	148	142	136	133	116	101	84	-2.1
Total EE/FSU	522	348	327	289	278	254	227	197	-2.1
Developing Countries									
Developing Asia	714	962	980	1,013	1,124	1,227	1,308	1,463	1.7
China	514	677	682	705	791	861	916	1,033	1.7
India	101	156	160	175	185	196	201	207	1.1
South Korea	21	30	34	34	34	38	40	41	0.7
Other Asia	78	98	103	99	115	132	151	182	2.4
Middle East	20	21	23	23	23	23	23	22	-0.1
Turkey	16	16	17	18	17	18	18	17	0.1
Africa	74	82	84	83	86	86	85	85	0.0
Central and South America	17	20	25	25	24	24	24	24	-0.1
Brazil	9	12	17	16	17	16	16	17	0.0
Other Central/South America	7	8	8	9	8	8	7	7	-0.4
Total Developing	825	1,085	1,111	1,144	1,256	1,359	1,440	1,593	1.5
Total World	2,287	2,319	2,343	2,374	2,471	2,551	2,612	2,731	0.6

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table C19; and World Energy Projection System (1999).

Table C14. World Nuclear Generating Capacity by Region and Country, Low Nuclear Case, 1996-2020
(Megawatts)

Region/Country	History		Projections				
	1996	1997	2000	2005	2010	2015	2020
Industrialized							
North America							
United States	100,817	99,046	94,836	86,589	72,102	44,989	31,798
Canada	14,902	11,994	10,298	10,298	10,298	6,276	2,643
Mexico	1,308	1,308	1,308	1,308	1,308	1,308	654
Industrialized Asia							
Japan	42,369	43,850	43,691	43,826	39,629	30,199	28,065
Western Europe							
Belgium	5,712	5,712	5,712	5,712	3,966	3,966	2,000
Finland	2,355	2,560	2,815	2,815	2,370	1,090	0
France	59,948	62,853	62,870	62,870	62,870	55,655	51,130
Germany	22,282	22,282	21,942	20,135	14,294	6,469	0
Netherlands	504	449	449	0	0	0	0
Spain	7,207	7,415	7,262	6,822	6,822	4,895	966
Sweden	10,040	10,040	9,440	8,390	4,202	0	0
Switzerland	3,077	3,079	3,079	3,194	2,829	2,115	1,145
United Kingdom	12,928	12,968	12,722	12,322	11,412	8,148	6,603
Total Industrialized	**283,449**	**283,556**	**276,424**	**264,281**	**232,102**	**165,090**	**125,004**
EE/FSU							
Eastern Europe							
Bulgaria	3,538	3,538	3,130	2,722	2,722	2,722	1,906
Czech Republic	1,648	1,648	1,648	2,560	2,560	2,560	912
Hungary	1,729	1,729	1,729	1,729	1,729	866	0
Romania	650	650	650	650	1,300	1,300	1,300
Slovak Republic	1,632	1,632	2,044	1,640	1,640	1,640	1,640
Slovenia	632	632	632	632	632	0	0
Former Soviet Union							
Armenia	376	376	376	376	0	0	0
Belarus	0	0	0	0	0	0	0
Kazakhstan	70	70	70	0	0	0	0
Lithuania	2,370	2,370	2,370	2,370	1,185	1,185	0
Russia	19,843	19,843	20,793	20,129	17,357	14,075	8,425
Ukraine	13,765	13,765	11,190	12,140	13,677	11,400	6,650
Total EE/FSU	**46,253**	**46,253**	**44,632**	**44,948**	**42,802**	**35,748**	**20,833**

See notes at end of table.

Table C14. World Nuclear Generating Capacity by Region and Country, Low Nuclear Case, 1996-2020 (Continued)
(Megawatts)

Region/Country	History		Projections				
	1996	1997	2000	2005	2010	2015	2020
Developing Countries							
Developing Asia							
China	2,167	2,167	2,167	6,737	8,737	8,737	8,737
India	1,695	1,695	1,395	2,249	4,422	4,112	4,112
Indonesia	0	0	0	0	0	0	0
Korea, North	0	0	0	0	0	0	0
Korea, South	9,120	9,770	11,380	12,340	11,784	12,450	10,660
Pakistan	125	125	125	300	300	300	300
Philippines	0	0	0	0	0	0	0
Taiwan	4,884	4,884	4,884	7,384	7,384	7,384	6,176
Thailand	0	0	0	0	0	0	0
Vietnam	0	0	0	0	0	0	0
Central and South America							
Argentina	935	935	935	600	1,292	1,292	692
Brazil	626	626	626	626	1,871	1,245	1,245
Cuba	0	0	0	0	0	0	0
Middle East							
Iran	0	0	0	0	0	0	0
Egypt	0	0	0	0	0	0	0
Turkey	0	0	0	0	0	0	0
Africa							
South Africa	1,842	1,842	1,842	1,842	1,842	0	0
Total Developing	21,394	22,044	23,354	32,078	37,632	35,520	31,922
Total World	351,096	351,853	344,410	341,307	312,536	236,358	177,759

Note: EE/FSU = Eastern Europe/Former Soviet Union.

Sources: **History:** International Atomic Energy Agency, *Nuclear Power Reactors in the World* (Vienna, Austria, April 1998). **Projections:** Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, based on detailed assessments of country-specific nuclear power plants.

Table C15. World Total Energy Consumption in Oil-Equivalent Units by Region, Low Economic Growth Case, 1990-2020
(Million Tons Oil Equivalent)

Region/Country	History 1990	1995	1996	Projections 2000	2005	2010	2015	2020	Average Annual Percent Change, 1996-2020
Industrialized Countries									
North America	**2,513**	**2,723**	**2,811**	**2,981**	**3,100**	**3,237**	**3,327**	**3,398**	**0.8**
United States[a]	2,115	2,278	2,352	2,489	2,570	2,676	2,740	2,784	0.7
Canada	274	307	317	333	349	363	371	380	0.7
Mexico	124	138	142	159	181	199	216	235	2.1
Western Europe	**1,511**	**1,570**	**1,613**	**1,669**	**1,724**	**1,770**	**1,815**	**1,861**	**0.6**
United Kingdom	236	233	249	258	269	277	284	292	0.7
France	235	257	267	273	279	286	292	298	0.5
Germany	372	358	365	375	388	400	411	422	0.6
Italy	168	179	183	187	195	202	208	215	0.7
Netherlands	83	89	92	97	100	103	106	109	0.7
Other Western Europe	419	453	458	478	492	502	513	526	0.6
Industrialized Asia	**579**	**663**	**678**	**644**	**688**	**706**	**726**	**745**	**0.4**
Japan	456	523	539	499	538	553	569	584	0.3
Australasia	123	140	139	145	149	153	157	161	0.6
Total Industrialized	**4,604**	**4,956**	**5,103**	**5,293**	**5,512**	**5,713**	**5,868**	**6,005**	**0.7**
EE/FSU									
Former Soviet Union	1,473	1,027	1,003	942	986	1,020	1,056	1,093	0.4
Eastern Europe	382	312	316	332	359	378	393	409	1.1
Total EE/FSU	**1,855**	**1,340**	**1,319**	**1,274**	**1,345**	**1,398**	**1,449**	**1,502**	**0.5**
Developing Countries									
Developing Asia	**1,294**	**1,811**	**1,879**	**1,981**	**2,304**	**2,585**	**2,854**	**3,143**	**2.2**
China	680	917	935	1,012	1,165	1,306	1,443	1,591	2.2
India	195	279	291	336	392	443	493	549	2.7
South Korea	93	165	180	174	207	237	266	296	2.1
Other Asia	327	449	473	459	540	600	651	707	1.7
Middle East	**331**	**413**	**436**	**465**	**515**	**565**	**612**	**663**	**1.8**
Turkey	50	63	67	76	83	91	99	108	2.0
Africa	**233**	**270**	**279**	**285**	**312**	**336**	**357**	**378**	**1.3**
Central and South America	**346**	**423**	**446**	**471**	**553**	**643**	**730**	**830**	**2.6**
Brazil	136	161	173	170	195	224	252	284	2.1
Other Central/South America	210	262	274	301	358	419	478	546	2.9
Total Developing	**2,203**	**2,917**	**3,039**	**3,201**	**3,683**	**4,129**	**4,553**	**5,014**	**2.1**
Total World	**8,663**	**9,212**	**9,461**	**9,769**	**10,541**	**11,240**	**11,870**	**12,520**	**1.2**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table C1; and World Energy Projection System (1999).

Appendix D

Projections of Oil Production Capacity and Oil Production in Five Cases:

- Reference
- High World Oil Price
- Low World Oil Price
- High Non-OPEC Supply
- Low Non-OPEC Supply

Table D1. World Oil Production Capacity by Region and Country, Reference Case, 1990-2020
(Million Barrels per Day)

Region/Country	History (Estimates)		Projections				
	1990	1997	2000	2005	2010	2015	2020
OPEC							
Persian Gulf							
Iran	3.2	3.9	4.0	4.3	4.5	4.9	5.5
Iraq	2.2	1.6	2.8	3.2	3.8	4.7	5.9
Kuwait	1.7	2.6	2.7	3.1	3.2	4.3	5.2
Qatar	0.5	0.6	0.5	0.6	0.6	0.6	0.7
Saudi Arabia	8.6	11.4	11.1	13.7	14.1	16.2	20.0
United Arab Emirates	2.5	2.7	2.8	3.2	3.4	4.2	4.9
Total Persian Gulf	**18.7**	**22.8**	**23.9**	**28.1**	**29.6**	**34.9**	**42.2**
Other OPEC							
Algeria	1.3	1.4	1.6	2.0	2.2	2.1	2.0
Indonesia	1.5	1.7	1.5	1.5	1.5	1.4	1.3
Libya	1.5	1.5	1.5	1.6	1.7	1.6	1.5
Nigeria	1.8	2.2	2.5	2.9	3.2	3.3	3.1
Venezuela	2.4	3.4	3.8	4.6	5.1	5.4	5.8
Total Other OPEC	**8.5**	**10.2**	**10.9**	**12.6**	**13.7**	**13.8**	**13.7**
Total OPEC	**27.2**	**33.0**	**34.8**	**40.7**	**43.3**	**48.7**	**55.9**
Non-OPEC							
Industrialized							
United States	9.7	9.5	9.1	9.0	9.0	8.9	8.7
Canada	2.0	2.6	2.6	3.0	3.2	3.4	3.4
Mexico	3.0	3.4	3.7	3.7	4.0	3.9	3.9
Australia	0.7	0.8	0.8	0.8	0.8	0.8	0.7
North Sea	4.2	6.3	6.9	7.2	7.0	6.4	5.9
Other	0.5	0.8	0.8	0.8	0.8	0.7	0.7
Total Industrialized	**20.1**	**23.4**	**24.1**	**24.5**	**24.8**	**24.1**	**23.3**
Eurasia							
China	2.8	3.2	3.2	3.3	3.5	3.6	3.6
Former Soviet Union	11.4	7.1	7.3	7.6	10.1	12.1	13.1
Eastern Europe	0.3	0.3	0.3	0.3	0.4	0.4	0.5
Total Eurasia	**14.5**	**10.6**	**10.8**	**11.2**	**14.0**	**16.1**	**17.2**
Other Non-OPEC							
Central and South America	2.4	3.4	3.8	4.0	4.4	4.8	5.0
Middle East	1.4	1.9	2.0	2.1	2.2	2.1	2.0
Africa	2.2	2.6	2.6	2.7	3.3	4.5	5.5
Asia	1.7	2.2	2.3	2.4	3.0	3.2	3.3
Total Other Non-OPEC	**7.7**	**10.1**	**10.7**	**11.2**	**12.9**	**14.6**	**15.8**
Total Non-OPEC	**42.3**	**44.1**	**45.6**	**46.9**	**51.7**	**54.8**	**56.3**
Total World	**69.5**	**77.1**	**80.4**	**87.6**	**95.0**	**103.5**	**112.2**

Note: OPEC = Organization of Petroleum Exporting Countries.

Sources: **History:** Energy Information Administration (EIA), Energy Markets and Contingency Information Division. **Projections:** EIA, Office of Integrated Analysis and Forecasting, World Energy Projection System and "DESTINY" International Energy Forecast Software (Dallas, TX: Petroconsultants, Fourth Quarter 1998).

Table D2. World Oil Production Capacity by Region and Country, High Oil Price Case, 1990-2020
(Million Barrels per Day)

Region/Country	History (Estimates) 1990	1997	Projections 2000	2005	2010	2015	2020
OPEC							
Persian Gulf							
Iran	3.2	3.9	3.9	4.1	4.2	4.3	4.5
Iraq	2.2	1.6	2.3	2.8	3.2	3.7	4.7
Kuwait	1.7	2.6	2.6	2.9	3.1	3.4	3.9
Qatar	0.5	0.6	0.5	0.6	0.6	0.6	0.7
Saudi Arabia	8.6	11.4	11.5	12.4	12.9	13.3	17.8
United Arab Emirates	2.5	2.7	2.7	3.0	3.1	3.3	3.7
Total Persian Gulf	**18.7**	**22.8**	**23.5**	**25.8**	**27.1**	**28.6**	**35.3**
Other OPEC							
Algeria	1.3	1.4	1.6	2.0	2.0	2.1	2.0
Indonesia	1.5	1.7	1.5	1.5	1.5	1.4	1.3
Libya	1.5	1.5	1.5	1.6	1.6	1.6	1.5
Nigeria	1.8	2.2	2.5	2.7	2.8	3.3	3.2
Venezuela	2.4	3.4	3.8	4.5	4.9	5.5	5.8
Total Other OPEC	**8.5**	**10.2**	**10.9**	**12.3**	**12.8**	**13.9**	**13.8**
Total OPEC	**27.2**	**33.0**	**34.4**	**38.1**	**39.9**	**42.5**	**49.1**
Non-OPEC							
Industrialized							
United States	9.7	9.5	9.3	9.3	9.5	9.6	9.3
Canada	2.0	2.6	2.9	3.0	3.3	3.4	3.5
Mexico	3.0	3.4	3.7	3.8	4.1	4.0	3.9
Australia	0.7	0.8	0.8	0.8	0.8	0.8	0.7
North Sea	4.2	6.3	6.9	7.3	7.1	6.6	6.1
Other	0.5	0.8	0.8	0.8	0.8	0.7	0.7
Total Industrialized	**20.1**	**23.4**	**24.4**	**25.0**	**25.6**	**25.1**	**24.2**
Eurasia							
China	2.8	3.2	3.2	3.4	3.6	3.7	3.7
Former Soviet Union	11.4	7.1	7.3	7.7	10.3	12.4	13.4
Eastern Europe	0.3	0.3	0.3	0.3	0.4	0.4	0.5
Total Eurasia	**14.5**	**10.6**	**10.8**	**11.4**	**14.3**	**16.5**	**17.6**
Other Non-OPEC							
Central and South America	2.4	3.4	3.9	4.1	4.5	4.9	5.1
Middle East	1.4	1.9	2.0	2.1	2.2	2.1	2.1
Africa	2.2	2.6	2.8	2.8	3.3	4.7	5.7
Asia	1.7	2.2	2.3	2.5	3.2	3.3	3.4
Total Other Non-OPEC	**7.7**	**10.1**	**11.0**	**11.5**	**13.2**	**15.0**	**16.3**
Total Non-OPEC	**42.3**	**44.1**	**46.2**	**47.9**	**53.1**	**56.6**	**58.1**
Total World	**69.5**	**77.1**	**80.6**	**86.0**	**93.0**	**99.1**	**107.2**

Note: OPEC = Organization of Petroleum Exporting Countries.

Sources: **History:** Energy Information Administration (EIA), Energy Markets and Contingency Information Division. **Projections:** EIA, Office of Integrated Analysis and Forecasting, World Energy Projection System and "DESTINY" International Energy Forecast Software (Dallas, TX: Petroconsultants, Fourth Quarter 1998).

Table D3. World Oil Production Capacity by Region and Country, Low Oil Price Case, 1990-2020
(Million Barrels per Day)

Region/Country	History (Estimates)		Projections				
	1990	1997	2000	2005	2010	2015	2020
OPEC							
Persian Gulf							
Iran	3.2	3.9	4.1	4.7	5.3	5.8	6.4
Iraq	2.2	1.6	2.9	3.5	4.4	5.4	7.2
Kuwait	1.7	2.6	2.7	3.3	3.7	4.2	4.9
Qatar	0.5	0.6	0.5	0.6	0.7	0.8	0.7
Saudi Arabia	8.6	11.4	11.2	14.8	17.3	21.9	27.4
United Arab Emirates	2.5	2.7	2.8	3.3	4.0	4.7	5.7
Total Persian Gulf	**18.7**	**22.8**	**24.2**	**30.2**	**35.4**	**42.8**	**52.3**
Other OPEC							
Algeria	1.3	1.4	1.8	2.3	2.3	2.2	2.1
Indonesia	1.5	1.7	1.7	1.7	1.6	1.5	1.4
Libya	1.5	1.5	1.5	1.8	1.9	1.8	1.6
Nigeria	1.8	2.2	2.6	3.0	3.5	3.6	3.8
Venezuela	2.4	3.4	4.2	5.4	6.3	6.8	6.7
Total Other OPEC	**8.5**	**10.2**	**11.8**	**14.2**	**15.6**	**15.9**	**15.6**
Total OPEC	**27.2**	**33.0**	**36.0**	**44.4**	**51.0**	**58.7**	**67.9**
Non-OPEC							
Industrialized							
United States	9.7	9.5	9.0	8.4	8.1	7.8	7.6
Canada	2.0	2.6	2.8	3.0	3.2	3.3	3.3
Mexico	3.0	3.4	3.6	3.7	3.9	3.8	3.7
Australia	0.7	0.8	0.8	0.8	0.8	0.8	0.7
North Sea	4.2	6.3	6.8	7.1	6.8	6.3	5.8
Other	0.5	0.8	0.8	0.8	0.8	0.7	0.7
Total Industrialized	**20.1**	**23.4**	**23.8**	**23.8**	**23.6**	**22.7**	**21.8**
Eurasia							
China	2.8	3.2	3.2	3.2	3.4	3.5	3.5
Former Soviet Union	11.4	7.1	7.2	7.4	9.8	11.7	12.6
Eastern Europe	0.3	0.3	0.3	0.3	0.4	0.4	0.4
Total Eurasia	**14.5**	**10.6**	**10.7**	**10.9**	**13.6**	**15.6**	**16.5**
Other Non-OPEC							
Central and South America	2.4	3.4	3.8	3.9	4.3	4.6	4.8
Middle East	1.4	1.9	2.0	2.1	2.1	2.0	2.0
Africa	2.2	2.6	2.6	2.6	3.2	4.3	5.3
Asia	1.7	2.2	2.3	2.4	2.8	3.1	3.1
Total Other Non-OPEC	**7.7**	**10.1**	**10.7**	**11.0**	**12.4**	**14.0**	**15.2**
Total Non-OPEC	**42.3**	**44.1**	**45.2**	**45.7**	**49.6**	**52.3**	**53.5**
Total World	**69.5**	**77.1**	**81.2**	**90.1**	**100.6**	**111.0**	**121.4**

Note: OPEC = Organization of Petroleum Exporting Countries.

Sources: **History:** Energy Information Administration (EIA), Energy Markets and Contingency Information Division. **Projections:** EIA, Office of Integrated Analysis and Forecasting, World Energy Projection System and "DESTINY" International Energy Forecast Software (Dallas, TX: Petroconsultants, Fourth Quarter 1998).

Table D4. World Oil Production Capacity by Region and Country, High Non-OPEC Supply Case, 1990-2020
(Million Barrels per Day)

Region/Country	History (Estimates) 1990	1997	Projections 2000	2005	2010	2015	2020
OPEC							
Persian Gulf							
Iran	3.2	3.9	3.9	4.0	4.1	4.4	5.1
Iraq	2.2	1.6	2.3	2.6	3.0	3.9	5.5
Kuwait	1.7	2.6	2.6	2.8	2.9	3.3	4.4
Qatar	0.5	0.6	0.5	0.6	0.6	0.6	0.7
Saudi Arabia	8.6	11.4	11.6	12.1	12.6	13.9	17.5
United Arab Emirates	2.5	2.7	2.7	2.8	2.9	3.3	3.9
Total Persian Gulf	**18.7**	**22.8**	**23.6**	**24.9**	**26.1**	**29.4**	**37.1**
Other OPEC							
Algeria	1.3	1.4	1.6	1.8	1.9	2.0	1.9
Indonesia	1.5	1.7	1.5	1.5	1.4	1.4	1.3
Libya	1.5	1.5	1.5	1.6	1.5	1.5	1.4
Nigeria	1.8	2.2	2.4	2.5	2.6	2.8	3.0
Venezuela	2.4	3.4	3.7	4.2	4.4	5.1	5.5
Total Other OPEC	**8.5**	**10.2**	**10.7**	**11.6**	**11.8**	**12.8**	**13.1**
Total OPEC	**27.2**	**33.0**	**34.3**	**36.5**	**37.9**	**42.2**	**50.2**
Non-OPEC							
Industrialized							
United States	9.7	9.5	9.2	9.1	9.4	9.3	9.1
Canada	2.0	2.6	2.9	3.2	3.4	3.7	3.8
Mexico	3.0	3.4	3.8	4.0	4.3	4.5	4.5
Australia	0.7	0.8	0.8	0.8	0.8	0.8	0.8
North Sea	4.2	6.3	7.2	7.6	7.5	6.9	6.3
Other	0.5	0.8	0.8	0.8	0.8	0.8	0.8
Total Industrialized	**20.1**	**23.4**	**24.7**	**25.5**	**26.2**	**26.0**	**25.3**
Eurasia							
China	2.8	3.2	3.3	3.6	3.9	4.0	3.9
Former Soviet Union	11.4	7.1	7.5	8.9	11.8	13.5	14.6
Eastern Europe	0.3	0.3	0.3	0.4	0.5	0.5	0.5
Total Eurasia	**14.5**	**10.6**	**11.1**	**12.9**	**16.2**	**18.0**	**19.0**
Other Non-OPEC							
Central and South America	2.4	3.4	4.1	4.6	5.1	5.5	5.7
Middle East	1.4	1.9	2.0	2.3	2.3	2.2	2.2
Africa	2.2	2.6	2.8	3.6	4.7	5.6	5.9
Asia	1.7	2.2	2.5	3.0	3.6	3.8	3.7
Total Other Non-OPEC	**7.7**	**10.1**	**11.4**	**13.5**	**15.7**	**17.1**	**17.5**
Total Non-OPEC	**42.3**	**44.1**	**47.2**	**51.9**	**58.1**	**61.1**	**61.8**
Total World	**69.5**	**77.1**	**81.5**	**88.4**	**96.0**	**103.3**	**112.0**

Note: OPEC = Organization of Petroleum Exporting Countries.

Sources: **History:** Energy Information Administration (EIA), Energy Markets and Contingency Information Division. **Projections:** EIA, Office of Integrated Analysis and Forecasting, World Energy Projection System and "DESTINY" International Energy Forecast Software (Dallas, TX: Petroconsultants, Fourth Quarter 1998).

Table D5. World Oil Production Capacity by Region and Country, Low Non-OPEC Supply Case, 1990-2020
(Million Barrels per Day)

Region/Country	History (Estimates)		Projections				
	1990	1997	2000	2005	2010	2015	2020
OPEC							
Persian Gulf							
Iran	3.2	3.9	4.0	4.7	5.2	5.6	6.3
Iraq	2.2	1.6	2.5	3.6	4.2	5.2	7.1
Kuwait	1.7	2.6	2.7	3.2	3.5	4.1	4.7
Qatar	0.5	0.6	0.6	0.7	0.7	0.8	0.7
Saudi Arabia	8.6	11.4	11.6	14.7	16.7	21.5	27.0
United Arab Emirates	2.5	2.7	2.8	3.3	3.7	4.5	5.5
Total Persian Gulf	**18.7**	**22.8**	**24.2**	**30.2**	**34.0**	**41.7**	**51.3**
Other OPEC							
Algeria	1.3	1.4	1.6	2.0	2.2	2.1	2.0
Indonesia	1.5	1.7	1.5	1.5	1.6	1.4	1.3
Libya	1.5	1.5	1.5	1.6	1.8	1.7	1.6
Nigeria	1.8	2.2	2.5	3.0	3.5	3.6	3.7
Venezuela	2.4	3.4	3.9	4.8	6.0	6.7	6.9
Total Other OPEC	**8.5**	**10.2**	**11.0**	**12.9**	**15.1**	**15.5**	**15.5**
Total OPEC	**27.2**	**33.0**	**35.2**	**43.1**	**49.1**	**57.2**	**66.8**
Non-OPEC							
Industrialized							
United States	9.7	9.5	9.1	8.8	8.6	8.4	8.1
Canada	2.0	2.6	2.7	2.8	2.9	3.0	2.8
Mexico	3.0	3.4	3.5	3.6	3.7	3.6	3.4
Australia	0.7	0.8	0.8	0.8	0.8	0.7	0.6
North Sea	4.2	6.3	6.8	6.4	5.8	5.1	4.2
Other	0.5	0.8	0.8	0.8	0.8	0.7	0.7
Total Industrialized	**20.1**	**23.4**	**23.7**	**23.2**	**22.6**	**21.5**	**19.8**
Eurasia							
China	2.8	3.2	3.2	3.2	3.3	3.3	3.2
Former Soviet Union	11.4	7.1	7.2	7.3	8.2	9.0	9.6
Eastern Europe	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Total Eurasia	**14.5**	**10.6**	**10.7**	**10.8**	**11.8**	**12.6**	**13.1**
Other Non-OPEC							
Central and South America	2.4	3.4	3.8	3.9	4.2	4.3	4.3
Middle East	1.4	1.9	2.0	2.1	2.1	2.0	1.9
Africa	2.2	2.6	2.6	2.5	2.8	3.5	4.0
Asia	1.7	2.2	2.3	2.4	2.6	2.8	2.7
Total Other Non-OPEC	**7.7**	**10.1**	**10.7**	**10.9**	**11.7**	**12.6**	**12.9**
Total Non-OPEC	**42.3**	**44.1**	**45.1**	**44.9**	**46.1**	**46.7**	**45.8**
Total World	**69.5**	**77.1**	**80.3**	**88.0**	**95.2**	**103.9**	**112.6**

Note: OPEC = Organization of Petroleum Exporting Countries.

Sources: **History:** Energy Information Administration (EIA), Energy Markets and Contingency Information Division. **Projections:** EIA, Office of Integrated Analysis and Forecasting, World Energy Projection System and "DESTINY" International Energy Forecast Software (Dallas, TX: Petroconsultants, Fourth Quarter 1998).

Table D5. World Oil Production by Region and Country, Reference Case, 1990-2020
(Million Barrels per Day)

Region/Country	History (Estimates) 1990	1997	Projections 2000	2005	2010	2015	2020
OPEC							
Persian Gulf	16.2	19.6	20.3	25.3	28.1	33.2	40.1
Other OPEC	8.3	10.2	10.7	12.3	13.4	13.5	13.4
Total OPEC	**24.5**	**29.8**	**31.0**	**37.6**	**41.5**	**46.7**	**53.5**
Non-OPEC							
Industrialized							
United States	9.7	9.5	9.1	9.0	9.0	8.9	8.7
Canada	2.0	2.6	2.8	3.0	3.2	3.4	3.4
Mexico	3.0	3.4	3.7	3.7	4.0	3.9	3.9
Western Europe	4.6	7.0	7.6	7.9	7.7	7.0	6.5
Other	0.8	0.9	0.9	0.9	0.9	0.9	0.8
Total Industrialized	**20.1**	**23.4**	**24.1**	**24.5**	**24.8**	**24.1**	**23.3**
Eurasia							
China	2.8	3.2	3.2	3.3	3.5	3.6	3.6
Former Soviet Union	11.4	7.1	7.3	7.6	10.1	12.1	13.1
Eastern Europe	0.3	0.3	0.3	0.3	0.4	0.4	0.5
Total Eurasia	**14.5**	**10.6**	**10.8**	**11.2**	**14.0**	**16.1**	**17.2**
Other Non-OPEC							
Central and South America	2.4	3.4	3.8	4.0	4.4	4.8	5.0
Pacific Rim	1.7	2.2	2.3	2.4	3.0	3.2	3.3
Other	3.5	4.5	4.6	4.8	5.5	6.6	7.5
Total Other Non-OPEC	**7.6**	**10.1**	**10.7**	**11.2**	**12.9**	**14.6**	**15.8**
Total World	**66.7**	**73.9**	**76.6**	**84.5**	**93.2**	**101.5**	**109.8**
Persian Gulf Production as a Percentage of World Consumption	**24.6**	**26.8**	**26.3**	**29.8**	**30.1**	**32.6**	**36.4**

Notes: OPEC = Organization of Petroleum Exporting Countries. Production includes crude oil (including lease condensates), natural gas liquids, other hydrogen and hydrocarbons for refinery feedstocks, refinery gains, alcohol, and liquids produced from coal and other sources. Totals may not equal sum of components due to independent rounding.

Sources: **History:** Energy Information Administration (EIA), Energy Markets and Contingency Information Division. **Projections:** EIA, Office of Integrated Analysis and Forecasting, World Energy Projection System and "DESTINY" International Energy Forecast Software (Dallas, TX: Petroconsultants, Fourth Quarter 1998).

Table D7. World Oil Production by Region and Country, High Oil Price Case, 1990-2020
(Million Barrels per Day)

Region/Country	History (Estimates)		Projections				
	1990	1997	2000	2005	2010	2015	2020
OPEC							
Persian Gulf	16.2	19.6	18.8	21.9	24.4	27.2	33.6
Other OPEC	8.3	10.2	10.4	11.7	12.2	13.2	13.1
Total OPEC	**24.5**	**29.8**	**29.2**	**33.6**	**36.6**	**40.4**	**46.7**
Non-OPEC							
Industrialized							
United States	9.7	9.5	9.3	9.3	9.5	9.6	9.3
Canada	2.0	2.6	2.9	3.0	3.3	3.4	3.5
Mexico	3.0	3.4	3.7	3.8	4.1	4.0	3.9
Western Europe	4.6	7.0	7.6	8.0	7.8	7.1	6.6
Other	0.8	0.9	0.9	0.9	0.9	1.0	0.9
Total Industrialized	**20.1**	**23.4**	**24.4**	**25.0**	**25.6**	**25.1**	**24.2**
Eurasia							
China	2.8	3.2	3.2	3.4	3.6	3.7	3.7
Former Soviet Union	11.4	7.1	7.3	7.7	10.3	12.4	13.4
Eastern Europe	0.3	0.3	0.3	0.3	0.4	0.4	0.5
Total Eurasia	**14.5**	**10.6**	**10.8**	**11.4**	**14.3**	**16.5**	**17.6**
Other Non-OPEC							
Central and South America	2.4	3.4	3.9	4.1	4.5	4.9	5.1
Pacific Rim	1.7	2.2	2.3	2.5	3.1	3.3	3.4
Other	3.5	4.5	4.8	4.9	5.6	6.8	7.8
Total Other Non-OPEC	**7.6**	**10.1**	**11.0**	**11.5**	**13.2**	**15.0**	**16.3**
Total World	**66.7**	**73.9**	**75.4**	**81.9**	**89.7**	**97.0**	**104.6**
Persian Gulf Production as a Percentage of World Consumption	**24.6**	**26.8**	**24.8**	**26.6**	**27.1**	**27.9**	**32.0**

Notes: OPEC = Organization of Petroleum Exporting Countries. Production includes crude oil (including lease condensates), natural gas liquids, other hydrogen and hydrocarbons for refinery feedstocks, refinery gains, alcohol, and liquids produced from coal and other sources. Totals may not equal sum of components due to independent rounding.

Sources: **History:** Energy Information Administration (EIA), Energy Markets and Contingency Information Division. **Projections:** EIA, Office of Integrated Analysis and Forecasting, World Energy Projection System and "DESTINY" International Energy Forecast Software (Dallas, TX: Petroconsultants, Fourth Quarter 1998).

Table D8. World Oil Production by Region and Country, Low Oil Price Case, 1990-2020
(Million Barrels per Day)

Region/Country	History (Estimates)		Projections				
	1990	1997	2000	2005	2010	2015	2020
OPEC							
Persian Gulf	16.2	19.6	21.8	28.1	33.6	40.7	49.7
Other OPEC	8.3	10.2	11.6	13.9	15.3	15.6	15.3
Total OPEC	**24.5**	**29.8**	**33.4**	**42.0**	**48.9**	**56.3**	**65.0**
Non-OPEC							
Industrialized							
United States	9.7	9.5	9.0	8.4	8.1	7.8	7.6
Canada	2.0	2.6	2.8	3.0	3.2	3.3	3.3
Mexico	3.0	3.4	3.6	3.7	3.9	3.8	3.7
Western Europe	4.6	7.0	7.5	7.8	7.5	7.0	6.4
Other	0.8	0.9	0.9	0.9	0.9	0.8	0.8
Total Industrialized	**20.1**	**23.4**	**23.8**	**23.8**	**23.6**	**22.7**	**21.8**
Eurasia							
China	2.8	3.2	3.2	3.2	3.4	3.5	3.5
Former Soviet Union	11.4	7.1	7.2	7.4	9.8	11.7	12.6
Eastern Europe	0.3	0.3	0.3	0.3	0.4	0.4	0.4
Total Eurasia	**14.5**	**10.6**	**10.7**	**10.9**	**13.6**	**15.6**	**16.5**
Other Non-OPEC							
Central and South America	2.4	3.4	3.8	3.9	4.3	4.6	4.8
Pacific Rim	1.7	2.2	2.3	2.4	2.8	3.1	3.1
Other	3.5	4.5	4.6	4.7	5.3	6.3	7.3
Total Other Non-OPEC	**7.6**	**10.1**	**10.7**	**11.0**	**12.4**	**14.0**	**15.2**
Total World	**66.7**	**73.9**	**78.6**	**87.7**	**98.5**	**108.6**	**118.5**
Persian Gulf Production as a Percentage of World Consumption	24.6	26.8	27.6	31.9	34.0	37.4	41.9

Notes: OPEC = Organization of Petroleum Exporting Countries. Production includes crude oil (including lease condensates), natural gas liquids, other hydrogen and hydrocarbons for refinery feedstocks, refinery gains, alcohol, and liquids produced from coal and other sources. Totals may not equal sum of components due to independent rounding.

Sources: **History:** Energy Information Administration (EIA), Energy Markets and Contingency Information Division. **Projections:** EIA, Office of Integrated Analysis and Forecasting, World Energy Projection System and "DESTINY" International Energy Forecast Software (Dallas, TX: Petroconsultants, Fourth Quarter 1998).

Table D9. World Oil Production by Region and Country, High Non-OPEC Supply Case, 1990-2020
(Million Barrels per Day)

Region/Country	History (Estimates)		Projections				
	1990	1997	2000	2005	2010	2015	2020
OPEC							
Persian Gulf	16.2	19.6	18.9	21.2	23.5	27.9	35.2
Other OPEC	8.3	10.2	10.5	11.4	11.6	12.5	12.8
Total OPEC	**24.5**	**29.8**	**29.4**	**32.6**	**35.1**	**40.4**	**48.0**
Non-OPEC							
Industrialized							
United States	9.7	9.5	9.2	9.1	9.4	9.3	9.1
Canada	2.0	2.6	2.9	3.2	3.4	3.7	3.8
Mexico	3.0	3.4	3.8	4.0	4.3	4.5	4.5
Western Europe	4.6	7.0	7.8	8.1	8.0	7.4	6.8
Other	0.8	0.9	1.0	1.1	1.1	1.1	1.1
Total Industrialized	**20.1**	**23.4**	**24.7**	**25.5**	**26.2**	**26.0**	**25.3**
Eurasia							
China	2.8	3.2	3.3	3.6	3.9	4.0	3.9
Former Soviet Union	11.4	7.1	7.5	8.9	11.8	13.5	14.6
Eastern Europe	0.3	0.3	0.3	0.4	0.5	0.5	0.5
Total Eurasia	**14.5**	**10.6**	**11.1**	**12.9**	**16.2**	**18.0**	**19.0**
Other Non-OPEC							
Central and South America	2.4	3.4	4.1	4.6	5.1	5.5	5.7
Pacific Rim	1.7	2.2	2.5	3.0	3.6	3.8	3.7
Other	3.5	4.5	4.8	5.9	7.0	7.8	8.1
Total Other Non-OPEC	**7.6**	**10.1**	**11.4**	**13.5**	**15.7**	**17.1**	**17.5**
Total World	**66.7**	**73.9**	**76.6**	**84.5**	**93.2**	**101.5**	**109.8**
Persian Gulf Production as a Percentage of World Consumption	**24.6**	**26.8**	**24.5**	**25.0**	**25.1**	**27.4**	**32.0**

Notes: OPEC = Organization of Petroleum Exporting Countries. Production includes crude oil (including lease condensates), natural gas liquids, other hydrogen and hydrocarbons for refinery feedstocks, refinery gains, alcohol, and liquids produced from coal and other sources. Totals may not equal sum of components due to independent rounding.

Sources: **History:** Energy Information Administration (EIA), Energy Markets and Contingency Information Division. **Projections:** EIA, Office of Integrated Analysis and Forecasting, World Energy Projection System and "DESTINY" International Energy Forecast Software (Dallas, TX: Petroconsultants, Fourth Quarter 1998).

Table D10. World Oil Production by Region and Country, Low Non-OPEC Supply Case, 1990-2020
(Million Barrels per Day)

Region/Country	History (Estimates)		Projections				
	1990	1997	2000	2005	2010	2015	2020
OPEC							
Persian Gulf	16.2	19.6	20.6	27.2	32.3	39.6	48.8
Other OPEC	8.3	10.2	10.8	12.4	14.8	15.2	15.2
Total OPEC	**24.5**	**29.8**	**31.4**	**39.6**	**47.1**	**54.8**	**64.0**
Non-OPEC							
Industrialized							
United States	9.7	9.5	9.1	8.8	8.6	8.4	8.1
Canada	2.0	2.6	2.7	2.8	2.9	3.0	2.8
Mexico	3.0	3.4	3.5	3.6	3.7	3.6	3.4
Western Europe	4.6	7.0	7.5	7.2	6.6	5.8	4.9
Other	0.8	0.9	0.9	0.8	0.8	0.7	0.6
Total Industrialized	**20.1**	**23.4**	**23.7**	**23.2**	**22.6**	**21.5**	**19.8**
Eurasia							
China	2.8	3.2	3.2	3.2	3.3	3.3	3.2
Former Soviet Union	11.4	7.1	7.2	7.3	8.2	9.0	9.6
Eastern Europe	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Total Eurasia	**14.5**	**10.6**	**10.7**	**10.8**	**11.8**	**12.6**	**13.1**
Other Non-OPEC							
Central and South America	2.4	3.4	3.8	3.9	4.2	4.3	4.3
Pacific Rim	1.7	2.2	2.3	2.4	2.6	2.8	2.7
Other	3.5	4.5	4.6	4.6	4.9	5.5	5.9
Total Other Non-OPEC	**7.6**	**10.1**	**10.7**	**10.9**	**11.7**	**12.6**	**12.9**
Total World	**66.7**	**73.9**	**76.6**	**84.5**	**93.2**	**101.5**	**109.8**
Persian Gulf Production as a Percentage of World Consumption	**24.6**	**26.8**	**26.7**	**32.1**	**34.6**	**38.9**	**44.3**

Notes: OPEC = Organization of Petroleum Exporting Countries. Production includes crude oil (including lease condensates), natural gas liquids, other hydrogen and hydrocarbons for refinery feedstocks, refinery gains, alcohol, and liquids produced from coal and other sources. Totals may not equal sum of components due to independent rounding.

Sources: **History:** Energy Information Administration (EIA), Energy Markets and Contingency Information Division. **Projections:** EIA, Office of Integrated Analysis and Forecasting, World Energy Projection System and "DESTINY" International Energy Forecast Software (Dallas, TX: Petroconsultants, Fourth Quarter 1998).

Appendix E

Projections of Transportation Energy Use in the Reference Case

Table E1. World Total Energy Consumption for Transportation by Region, Reference Case, 1990-2020
(Million Barrels of Oil per Day)

Region/Country	History 1990	History 1996	Projections 2000	Projections 2005	Projections 2010	Projections 2015	Projections 2020	Average Annual Percent Change, 1996-2020
Industrialized Countries								
North America	**12.5**	**13.9**	**15.1**	**16.9**	**18.6**	**20.0**	**21.4**	**1.8**
United States[a]	11.0	12.1	13.2	14.7	16.1	17.0	18.0	1.7
Canada	0.9	1.0	1.1	1.2	1.3	1.3	1.4	1.3
Mexico	0.6	0.7	0.8	1.0	1.3	1.6	2.0	4.4
Western Europe	**6.2**	**6.9**	**7.4**	**7.9**	**8.4**	**8.7**	**9.1**	**1.1**
United Kingdom	1.0	1.0	1.1	1.2	1.3	1.4	1.5	1.5
France	0.9	1.0	1.1	1.2	1.2	1.3	1.3	1.2
Germany	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.2
Italy	0.7	0.8	0.9	0.9	1.0	1.0	1.0	0.8
Netherlands	0.4	0.5	0.5	0.5	0.6	0.6	0.6	1.0
Other Western Europe	2.0	2.3	2.4	2.6	2.7	2.8	2.9	1.1
Industrialized Asia	**2.1**	**2.5**	**2.6**	**2.8**	**2.9**	**3.1**	**3.2**	**1.1**
Japan	1.6	1.9	1.9	2.1	2.2	2.2	2.3	0.9
Australasia	0.5	0.6	0.7	0.7	0.8	0.8	0.9	1.7
Total Industrialized	**20.9**	**23.3**	**25.2**	**27.6**	**29.9**	**31.8**	**33.7**	**1.6**
EE/FSU								
Former Soviet Union	2.7	1.3	1.4	1.7	1.9	2.1	2.2	2.4
Eastern Europe	0.6	0.5	0.7	0.8	1.0	1.0	1.1	3.1
Total EE/FSU	**3.3**	**1.8**	**2.1**	**2.6**	**2.9**	**3.1**	**3.3**	**2.6**
Developing Countries								
Developing Asia	**3.1**	**4.8**	**5.7**	**7.6**	**9.4**	**11.7**	**12.9**	**4.2**
China	0.8	1.2	1.6	2.4	3.7	5.3	5.9	6.7
India	0.5	0.8	1.1	1.4	1.5	1.7	1.8	3.5
South Korea	0.3	0.7	0.8	0.9	1.1	1.2	1.3	3.0
Other Asia	1.4	2.1	2.3	2.7	3.1	3.5	3.9	2.6
Middle East	**1.2**	**1.7**	**1.9**	**2.2**	**2.6**	**3.1**	**3.7**	**3.2**
Turkey	0.2	0.3	0.3	0.4	0.5	0.5	0.6	3.0
Africa	**0.9**	**1.0**	**1.1**	**1.3**	**1.5**	**1.8**	**2.1**	**3.1**
Central and South America	**1.6**	**2.0**	**2.1**	**2.7**	**3.4**	**4.3**	**5.4**	**4.2**
Brazil	0.7	0.8	0.9	1.1	1.4	1.7	2.1	3.8
Other Central/South America	0.9	1.2	1.3	1.6	2.1	2.6	3.3	4.5
Total Developing	**6.8**	**9.5**	**10.8**	**13.6**	**17.0**	**20.9**	**24.2**	**3.9**
Total World	**31.0**	**34.6**	**38.1**	**43.8**	**49.9**	**55.8**	**61.3**	**2.4**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.
Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding.
Sources: **History:** Derived from Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

Table E2. World Total Gasoline Consumption for Transportation by Region, Reference Case, 1990-2020
(Million Barrels of Oil per Day)

Region/Country	History		Projections					Average Annual Percent Change, 1996-2020
	1990	1996	2000	2005	2010	2015	2020	
Industrialized Countries								
North America	**7.6**	**8.5**	**9.3**	**10.3**	**11.1**	**11.7**	**12.4**	**1.6**
United States[a]	6.7	7.4	8.1	8.9	9.6	9.9	10.3	1.4
Canada	0.5	0.6	0.6	0.6	0.7	0.7	0.7	1.1
Mexico	0.4	0.5	0.6	0.7	0.9	1.1	1.3	4.3
Western Europe	**2.6**	**2.7**	**2.9**	**3.0**	**3.0**	**3.0**	**3.0**	**0.5**
United Kingdom	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.7
France	0.4	0.3	0.4	0.4	0.4	0.4	0.4	0.3
Germany	0.7	0.6	0.7	0.7	0.7	0.7	0.7	0.5
Italy	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Netherlands	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.8
Other Western Europe	0.7	0.8	0.9	0.9	0.9	0.9	0.9	0.4
Industrialized Asia	**1.0**	**1.1**	**1.2**	**1.2**	**1.3**	**1.3**	**1.3**	**0.6**
Japan	0.7	0.8	0.8	0.9	0.9	0.9	0.9	0.3
Australasia	0.3	0.3	0.3	0.4	0.4	0.4	0.4	1.1
Total Industrialized	**11.3**	**12.3**	**13.4**	**14.5**	**15.4**	**16.1**	**16.7**	**1.3**
EE/FSU								
Former Soviet Union	1.1	0.3	0.5	0.6	0.7	0.7	0.8	3.4
Eastern Europe	0.3	0.3	0.3	0.4	0.5	0.5	0.5	2.7
Total EE/FSU	**1.3**	**0.6**	**0.8**	**1.0**	**1.1**	**1.2**	**1.2**	**3.1**
Developing Countries								
Developing Asia	**1.0**	**1.6**	**2.0**	**2.7**	**3.7**	**4.7**	**5.0**	**4.9**
China	0.4	0.7	0.9	1.5	2.3	3.3	3.5	7.1
India	0.1	0.1	0.1	0.2	0.2	0.2	0.2	2.5
South Korea	0.1	0.2	0.2	0.2	0.3	0.3	0.3	2.6
Other Asia	0.4	0.6	0.7	0.8	0.9	0.9	1.0	2.0
Middle East	**0.6**	**0.8**	**0.8**	**0.9**	**1.1**	**1.4**	**1.6**	**3.3**
Turkey	0.1	0.1	0.1	0.1	0.2	0.2	0.2	2.4
Africa	**0.4**	**0.5**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**3.0**
Central and South America	**0.6**	**0.9**	**0.9**	**1.2**	**1.5**	**1.9**	**2.4**	**4.5**
Brazil	0.1	0.2	0.2	0.3	0.4	0.4	0.6	3.9
Other Central/South America	0.5	0.6	0.7	0.9	1.2	1.5	1.9	4.6
Total Developing	**2.5**	**3.6**	**4.2**	**5.4**	**7.0**	**8.8**	**10.0**	**4.3**
Total World	**15.1**	**16.5**	**18.3**	**20.9**	**23.6**	**26.1**	**27.9**	**2.2**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding.

Sources: **History:** Derived from Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

Table E3. World Total Diesel Fuel Consumption for Transportation by Region, Reference Case, 1990-2020
(Million Barrels of Oil per Day)

Region/Country	History 1990	History 1996	Projections 2000	Projections 2005	Projections 2010	Projections 2015	Projections 2020	Average Annual Percent Change, 1996-2020
Industrialized Countries								
North America	2.4	2.7	2.9	3.3	3.7	4.0	4.3	1.9
United States[a]	2.0	2.3	2.5	2.8	3.1	3.3	3.5	1.8
Canada	0.2	0.2	0.2	0.3	0.3	0.3	0.3	1.6
Mexico	0.2	0.2	0.2	0.3	0.3	0.4	0.5	4.0
Western Europe	2.2	2.6	2.9	3.1	3.2	3.4	3.5	1.2
United Kingdom	0.3	0.3	0.4	0.4	0.4	0.4	0.5	1.6
France	0.4	0.5	0.5	0.6	0.6	0.7	0.7	1.4
Germany	0.4	0.5	0.5	0.6	0.6	0.7	0.7	1.4
Italy	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.8
Netherlands	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.9
Other Western Europe	0.7	0.9	0.9	1.0	1.0	1.1	1.1	0.9
Industrialized Asia	0.6	0.8	0.8	0.9	1.0	1.0	1.1	1.3
Japan	0.5	0.7	0.7	0.8	0.8	0.8	0.9	1.1
Australasia	0.1	0.1	0.1	0.2	0.2	0.2	0.2	2.0
Total Industrialized	5.2	6.1	6.6	7.3	7.9	8.4	8.8	1.5
EE/FSU								
Former Soviet Union	0.6	0.3	0.4	0.5	0.5	0.6	0.7	3.1
Eastern Europe	0.2	0.2	0.2	0.3	0.3	0.4	0.4	3.3
Total EE/FSU	0.8	0.5	0.6	0.8	0.9	1.0	1.1	3.2
Developing Countries								
Developing Asia	1.2	2.1	2.5	3.2	3.9	4.6	5.0	3.8
China	0.2	0.3	0.4	0.6	1.0	1.4	1.7	7.3
India	0.4	0.6	0.8	1.1	1.2	1.3	1.4	3.2
South Korea	0.2	0.3	0.4	0.5	0.5	0.6	0.6	2.7
Other Asia	0.5	0.8	0.9	1.1	1.2	1.3	1.4	2.3
Middle East	0.3	0.5	0.6	0.7	0.8	0.9	1.1	3.3
Turkey	0.1	0.1	0.2	0.2	0.2	0.2	0.3	2.7
Africa	0.3	0.3	0.3	0.3	0.4	0.5	0.6	3.2
Central and South America	0.6	0.7	0.7	0.9	1.2	1.5	1.9	4.1
Brazil	0.3	0.4	0.4	0.5	0.6	0.8	1.0	3.8
Other Central/South America	0.2	0.3	0.3	0.4	0.6	0.7	0.9	4.4
Total Developing	2.4	3.6	4.1	5.2	6.3	7.5	8.6	3.7
Total World	8.4	10.2	11.4	13.2	15.0	16.8	18.4	2.5

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding.

Sources: **History:** Derived from Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

Table E4. World Total Jet Fuel Consumption for Transportation by Region, Reference Case, 1990-2020
(Million Barrels of Oil per Day)

Region/Country	History		Projections					Average Annual Percent Change, 1996-2020
	1990	1996	2000	2005	2010	2015	2020	
Industrialized Countries								
North America	**1.7**	**1.8**	**2.0**	**2.3**	**2.8**	**3.1**	**3.5**	**2.8**
United States[a]	1.6	1.6	1.9	2.2	2.5	2.8	3.1	2.7
Canada	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1.4
Mexico	0.0	0.0	0.1	0.1	0.1	0.2	0.2	6.3
Western Europe	**0.6**	**0.8**	**0.9**	**1.0**	**1.2**	**1.4**	**1.7**	**3.3**
United Kingdom	0.1	0.2	0.2	0.2	0.3	0.3	0.4	3.4
France	0.1	0.1	0.1	0.1	0.1	0.2	0.2	2.9
Germany	0.1	0.1	0.1	0.2	0.2	0.2	0.3	3.4
Italy	0.0	0.1	0.1	0.1	0.1	0.1	0.1	3.2
Netherlands	0.0	0.1	0.1	0.1	0.1	0.1	0.1	3.4
Other Western Europe	0.2	0.3	0.3	0.4	0.4	0.5	0.6	3.4
Industrialized Asia	**0.2**	**0.3**	**0.3**	**0.3**	**0.4**	**0.5**	**0.5**	**2.5**
Japan	0.1	0.2	0.2	0.2	0.2	0.3	0.3	2.2
Australasia	0.1	0.1	0.1	0.1	0.1	0.2	0.2	3.1
Total Industrialized	**2.5**	**2.8**	**3.2**	**3.7**	**4.4**	**5.0**	**5.7**	**2.9**
EE/FSU								
Former Soviet Union	0.4	0.2	0.2	0.2	0.2	0.3	0.3	1.6
Eastern Europe	0.0	0.0	0.0	0.1	0.1	0.1	0.1	5.6
Total EE/FSU	**0.5**	**0.3**	**0.2**	**0.3**	**0.3**	**0.4**	**0.5**	**2.4**
Developing Countries								
Developing Asia	**0.3**	**0.5**	**0.5**	**0.7**	**1.0**	**1.4**	**2.0**	**6.1**
China	0.0	0.1	0.1	0.1	0.2	0.3	0.5	8.7
India	0.0	0.0	0.1	0.1	0.1	0.2	0.3	7.2
South Korea	0.0	0.0	0.0	0.1	0.1	0.1	0.2	6.3
Other Asia	0.2	0.3	0.3	0.4	0.6	0.8	1.0	5.0
Middle East	**0.1**	**0.2**	**0.2**	**0.2**	**0.3**	**0.4**	**0.5**	**5.5**
Turkey	0.0	0.0	0.0	0.0	0.1	0.1	0.1	6.0
Africa	**0.1**	**0.1**	**0.1**	**0.2**	**0.2**	**0.3**	**0.3**	**4.7**
Central and South America	**0.1**	**0.1**	**0.2**	**0.2**	**0.3**	**0.4**	**0.6**	**5.7**
Brazil	0.0	0.0	0.0	0.1	0.1	0.1	0.2	5.2
Other Central/South America	0.1	0.1	0.1	0.2	0.2	0.3	0.4	5.9
Total Developing	**0.6**	**0.9**	**1.0**	**1.4**	**1.9**	**2.5**	**3.4**	**5.8**
Total World	**3.6**	**4.0**	**4.4**	**5.4**	**6.6**	**7.9**	**9.5**	**3.7**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding.

Sources: **History:** Derived from Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

Table E5. World Total Residual Fuel Consumption for Transportation by Region, Reference Case, 1990-2020
(Million Barrels of Oil per Day)

Region/Country	History		Projections					Average Annual Percent Change, 1996-2020
	1990	1996	2000	2005	2010	2015	2020	
Industrialized Countries								
North America	**0.6**	**0.5**	**0.5**	**0.5**	**0.6**	**0.6**	**0.7**	**1.4**
United States[a]	0.5	0.5	0.4	0.5	0.6	0.6	0.7	1.5
Canada	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
Mexico	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
Western Europe	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.3**
United Kingdom	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
France	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.3
Germany	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Italy	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Netherlands	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3
Other Western Europe	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3
Industrialized Asia	**0.1**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.5**
Japan	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.5
Australasia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
Total Industrialized	**1.3**	**1.3**	**1.2**	**1.3**	**1.4**	**1.4**	**1.5**	**0.8**
EE/FSU								
Former Soviet Union	0.2	0.1	0.1	0.1	0.1	0.1	0.1	1.0
Eastern Europe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9
Total EE/FSU	**0.2**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**1.3**
Developing Countries								
Developing Asia	**0.3**	**0.5**	**0.5**	**0.6**	**0.6**	**0.7**	**0.8**	**1.6**
China	0.0	0.1	0.1	0.1	0.1	0.1	0.1	2.3
India	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0
South Korea	0.0	0.1	0.1	0.1	0.2	0.2	0.2	1.6
Other Asia	0.3	0.3	0.3	0.3	0.4	0.4	0.4	1.4
Middle East	**0.2**	**0.3**	**0.3**	**0.3**	**0.4**	**0.4**	**0.4**	**1.4**
Turkey	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4
Africa	**0.1**	**0.1**	**0.1**	**0.1**	**0.2**	**0.2**	**0.2**	**1.2**
Central and South America	**0.1**	**0.1**	**0.1**	**0.2**	**0.2**	**0.2**	**0.2**	**0.8**
Brazil	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.9
Other Central/South America	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.8
Total Developing	**0.8**	**1.1**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**	**1.4**
Total World	**2.3**	**2.4**	**2.4**	**2.6**	**2.8**	**2.9**	**3.1**	**1.1**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding.

Sources: **History:** Derived from Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

Table E6. World Total Other Fuel Consumption for Transportation by Region, Reference Case, 1990-2020
(Million Barrels of Oil per Day)

Region/Country	History 1990	History 1996	Projections 2000	Projections 2005	Projections 2010	Projections 2015	Projections 2020	Average Annual Percent Change, 1996-2020
Industrialized Countries								
North America	0.5	0.6	0.6	0.6	0.7	0.8	0.8	1.5
United States[a]	0.4	0.4	0.4	0.5	0.5	0.5	0.6	1.4
Canada	0.1	0.1	0.2	0.2	0.2	0.2	0.2	1.5
Mexico	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.9
Western Europe	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.5
United Kingdom	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
France	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Germany	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Italy	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.5
Netherlands	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
Other Western Europe	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.5
Industrialized Asia	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.8
Japan	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.6
Australasia	0.0	0.0	0.0	0.0	0.0	0.1	0.1	1.3
Total Industrialized	0.9	1.0	1.0	1.1	1.2	1.2	1.3	1.2
EE/FSU								
Former Soviet Union	0.5	0.4	0.4	0.4	0.4	0.5	0.5	0.9
Eastern Europe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5
Total EE/FSU	0.5	0.4	0.4	0.5	0.5	0.5	0.5	1.0
Developing Countries								
Developing Asia	0.4	0.3	0.3	0.3	0.4	0.4	0.4	1.3
China	0.2	0.2	0.2	0.2	0.2	0.2	0.2	1.0
India	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.9
South Korea	0.0	0.0	0.1	0.1	0.1	0.1	0.1	2.5
Other Asia	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.9
Middle East	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5
Turkey	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5
Africa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8
Central and South America	0.1	0.2	0.2	0.2	0.3	0.3	0.4	3.8
Brazil	0.1	0.1	0.1	0.2	0.2	0.3	0.4	3.9
Other Central/South America	0.0	0.0	0.0	0.0	0.1	0.1	0.1	3.8
Total Developing	0.5	0.5	0.5	0.6	0.7	0.8	0.9	2.4
Total World	1.9	1.9	1.9	2.1	2.3	2.5	2.7	1.5

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding.

Sources: History: Derived from Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

Table E7. World Total Road Use Energy Consumption by Region, Reference Case, 1990-2020
(Million Barrels of Oil per Day)

Region/Country	History 1990	History 1996	Projections 2000	Projections 2005	Projections 2010	Projections 2015	Projections 2020	Average Annual Percent Change, 1996-2020
Industrialized Countries								
North America	9.4	10.6	11.7	13.0	14.2	15.0	16.0	1.7
United States[a]	8.1	9.2	10.1	11.2	12.1	12.6	13.2	1.5
Canada	0.7	0.7	0.8	0.9	0.9	1.0	1.0	1.3
Mexico	0.6	0.7	0.8	0.9	1.2	1.4	1.8	4.3
Western Europe	4.6	5.1	5.5	5.8	6.1	6.2	6.3	0.9
United Kingdom	0.7	0.8	0.8	0.9	0.9	1.0	1.0	1.1
France	0.7	0.8	0.9	0.9	1.0	1.0	1.0	1.0
Germany	1.0	1.1	1.2	1.3	1.3	1.4	1.4	0.9
Italy	0.6	0.7	0.7	0.8	0.8	0.8	0.8	0.6
Netherlands	0.2	0.2	0.2	0.2	0.2	0.2	0.2	1.0
Other Western Europe	1.4	1.6	1.7	1.8	1.8	1.8	1.9	0.7
Industrialized Asia	1.6	1.9	2.0	2.1	2.2	2.3	2.3	0.9
Japan	1.2	1.4	1.5	1.6	1.7	1.7	1.7	0.7
Australasia	0.4	0.5	0.5	0.5	0.6	0.6	0.6	1.4
Total Industrialized	15.6	17.6	19.2	21.0	22.5	23.5	24.6	1.4
EE/FSU								
Former Soviet Union	1.5	0.5	0.7	0.9	1.1	1.2	1.3	3.8
Eastern Europe	0.5	0.4	0.6	0.7	0.8	0.9	0.9	3.0
Total EE/FSU	2.0	0.9	1.3	1.7	1.9	2.1	2.1	3.5
Developing Countries								
Developing Asia	2.0	3.3	4.2	5.6	7.2	8.9	9.6	4.5
China	0.5	0.8	1.2	1.9	3.1	4.5	4.9	7.8
India	0.4	0.7	0.9	1.2	1.3	1.4	1.5	3.3
South Korea	0.2	0.4	0.6	0.7	0.8	0.8	0.9	2.9
Other Asia	0.9	1.4	1.5	1.8	2.0	2.1	2.3	2.2
Middle East	0.8	1.3	1.4	1.6	1.9	2.3	2.8	3.3
Turkey	0.2	0.2	0.3	0.3	0.4	0.4	0.4	2.7
Africa	0.6	0.7	0.7	0.9	1.1	1.2	1.4	3.2
Central and South America	1.3	1.7	1.7	2.2	2.9	3.6	4.6	4.3
Brazil	0.6	0.7	0.7	0.9	1.2	1.5	1.8	3.9
Other Central/South America	0.7	0.9	1.0	1.3	1.7	2.2	2.8	4.6
Total Developing	4.7	6.9	8.0	10.3	13.1	16.1	18.4	4.2
Total World	22.3	25.5	28.5	33.0	37.4	41.7	45.2	2.4

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding.

Sources: **History:** Derived from Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

Table E8. World Total Air Use Energy Consumption by Region, Reference Case, 1990-2020
(Million Barrels of Oil per Day)

Region/Country	History		Projections					Average Annual Percent Change, 1996-2020
	1990	1996	2000	2005	2010	2015	2020	
Industrialized Countries								
North America	**1.7**	**1.8**	**2.1**	**2.4**	**2.8**	**3.1**	**3.5**	**2.8**
United States[a]	1.6	1.7	1.9	2.2	2.6	2.9	3.2	2.7
Canada	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1.4
Mexico	0.0	0.0	0.1	0.1	0.1	0.2	0.2	6.3
Western Europe	**0.6**	**0.8**	**0.9**	**1.0**	**1.2**	**1.4**	**1.7**	**3.3**
United Kingdom	0.1	0.2	0.2	0.2	0.3	0.3	0.4	3.4
France	0.1	0.1	0.1	0.1	0.2	0.2	0.2	2.9
Germany	0.1	0.1	0.1	0.2	0.2	0.2	0.3	3.4
Italy	0.0	0.1	0.1	0.1	0.1	0.1	0.1	3.2
Netherlands	0.0	0.1	0.1	0.1	0.1	0.1	0.1	3.4
Other Western Europe	0.2	0.3	0.3	0.4	0.4	0.5	0.6	3.4
Industrialized Asia	**0.2**	**0.3**	**0.3**	**0.3**	**0.4**	**0.5**	**0.5**	**2.6**
Japan	0.1	0.2	0.2	0.2	0.2	0.3	0.3	2.2
Australasia	0.1	0.1	0.1	0.1	0.1	0.2	0.2	3.1
Total Industrialized	**2.5**	**2.9**	**3.2**	**3.8**	**4.4**	**5.0**	**5.7**	**2.9**
EE/FSU								
Former Soviet Union	0.4	0.2	0.2	0.2	0.2	0.3	0.3	1.6
Eastern Europe	0.0	0.0	0.0	0.1	0.1	0.1	0.1	5.6
Total EE/FSU	**0.5**	**0.3**	**0.2**	**0.3**	**0.3**	**0.4**	**0.5**	**2.4**
Developing Countries								
Developing Asia	**0.3**	**0.5**	**0.5**	**0.7**	**1.0**	**1.4**	**2.0**	**6.1**
China	0.0	0.1	0.1	0.1	0.2	0.3	0.5	8.7
India	0.0	0.0	0.1	0.1	0.1	0.2	0.3	7.2
South Korea	0.0	0.0	0.0	0.1	0.1	0.1	0.2	6.3
Other Asia	0.2	0.3	0.3	0.4	0.6	0.8	1.0	5.0
Middle East	**0.1**	**0.2**	**0.2**	**0.2**	**0.3**	**0.4**	**0.5**	**5.5**
Turkey	0.0	0.0	0.0	0.0	0.1	0.1	0.1	6.0
Africa	**0.1**	**0.1**	**0.1**	**0.2**	**0.2**	**0.3**	**0.4**	**4.7**
Central and South America	**0.1**	**0.1**	**0.2**	**0.2**	**0.3**	**0.4**	**0.6**	**5.7**
Brazil	0.0	0.0	0.0	0.1	0.1	0.1	0.2	5.2
Other Central/South America	0.1	0.1	0.1	0.2	0.2	0.3	0.4	5.9
Total Developing	**0.6**	**0.9**	**1.0**	**1.4**	**1.9**	**2.6**	**3.4**	**5.8**
Total World	**3.7**	**4.0**	**4.4**	**5.4**	**6.6**	**8.0**	**9.6**	**3.7**

[a]*Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.*

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding.

Sources: **History:** Derived from Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

Table E9. World Total Other Transportation Use Energy Consumption by Region, Reference Case, 1990-2020
(Million Barrels of Oil per Day)

Region/Country	History 1990	History 1996	Projections 2000	Projections 2005	Projections 2010	Projections 2015	Projections 2020	Average Annual Percent Change, 1996-2020
Industrialized Countries								
North America	**1.5**	**1.4**	**1.4**	**1.5**	**1.7**	**1.8**	**2.0**	**1.3**
United States[a]	1.3	1.2	1.2	1.3	1.4	1.6	1.7	1.3
Canada	0.2	0.2	0.2	0.2	0.2	0.2	0.3	1.2
Mexico	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
Western Europe	**1.0**	**1.0**	**1.0**	**1.1**	**1.1**	**1.1**	**1.1**	**0.3**
United Kingdom	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3
France	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2
Germany	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2
Italy	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3
Netherlands	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3
Other Western Europe	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.3
Industrialized Asia	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.5**
Japan	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.5
Australasia	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.7
Total Industrialized	**2.7**	**2.8**	**2.7**	**2.9**	**3.1**	**3.2**	**3.4**	**0.9**
EE/FSU								
Former Soviet Union	0.8	0.5	0.5	0.6	0.6	0.6	0.7	0.8
Eastern Europe	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1.1
Total EE/FSU	**0.8**	**0.6**	**0.6**	**0.6**	**0.7**	**0.7**	**0.7**	**0.8**
Developing Countries								
Developing Asia	**0.9**	**1.0**	**1.0**	**1.1**	**1.2**	**1.3**	**1.4**	**1.3**
China	0.3	0.4	0.4	0.4	0.4	0.5	0.6	1.2
India	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.8
South Korea	0.1	0.2	0.2	0.2	0.2	0.2	0.2	1.5
Other Asia	0.4	0.4	0.4	0.5	0.5	0.5	0.6	1.3
Middle East	**0.2**	**0.3**	**0.3**	**0.4**	**0.4**	**0.4**	**0.4**	**1.4**
Turkey	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
Africa	**0.1**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.3**	**1.1**
Central and South America	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.3**	**0.9**
Brazil	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.9
Other Central/South America	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.9
Total Developing	**1.5**	**1.8**	**1.8**	**1.9**	**2.1**	**2.2**	**2.4**	**1.2**
Total World	**5.0**	**5.1**	**5.1**	**5.4**	**5.8**	**6.1**	**6.5**	**1.0**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding.

Sources: **History:** Derived from Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

Appendix F
World Energy Projection System

The projections of world energy consumption published annually by the Energy Information Administration (EIA) in the *International Energy Outlook (IEO)* are derived from the World Energy Projection System (WEPS). WEPS is an integrated set of personal-computer-based spreadsheets containing data compilations, assumption specifications, descriptive analysis procedures, and projection models. The WEPS accounting framework incorporates projections from independently documented models and assumptions about the future energy intensity of economic activity (ratios of total energy consumption divided by gross domestic product [GDP]) and about the rate of incremental energy requirements met by natural gas, coal, and renewable energy sources (hydroelectricity, geothermal, solar, wind, biomass, and other renewable sources).

WEPS provides projections of total world primary energy consumption, as well as projections of energy consumption by primary energy type (oil, natural gas, coal, nuclear, and hydroelectric and other renewable resources), and projections of net electricity consumption. By fuel projections of energy consumed for electricity generation and energy consumed at the transportation sector are also provided. Carbon emissions resulting from fossil fuel use are derived from the energy consumption projections. All projections are computed in 5-year intervals through the year 2020. For both historical series and projection series, WEPS provides analytical computations of energy intensity and energy elasticity (the percentage change in energy consumption per percentage change in GDP).

WEPS projections are provided for regions and selected countries. Projections are made for 14 individual countries, 9 of which—United States, Canada, Mexico, Japan, United Kingdom, France, Germany, Italy, and Netherlands—are part of the designation "industrialized countries." Individual country projections are also made for China, India, South Korea, Turkey, and Brazil, all of which are considered "developing countries." Beyond these individual countries, the rest of the world is divided into regions. Industrialized regions include North America (Canada, Mexico, and the United States), Western Europe (United Kingdom, France, Germany, Italy, and Netherlands, and Other Europe), and Pacific (Japan and Australasia—Australia, New Zealand, and the U.S. Territories). Developing regions include developing Asia (China, India, South Korea, and Other Asia), Middle East (Turkey, and Other Middle East), Africa, and Central and South America (Brazil and Other Central and South America). The transitional economies consisting of the countries in Eastern Europe (EE) and the former Soviet Union (FSU) are considered as a separate country grouping, neither industrialized nor developing.

The process of creating the projections begins with the calculation of a reference case total energy consumption projection for each country or region for each 5-year interval in the forecast period. The total energy consumption projection for each forecast year is the product of an assumed GDP growth rate, an assumed energy elasticity, and the total energy consumption for the prior forecast year. For the first year of the forecast, the prior year consumption is based on historical data. Subsequent calculations are based on the energy consumption projections for the preceding years.

Projections of world oil supply are provided to WEPS from EIA's International Energy Module, which is a submodule of the National Energy Modeling System (NEMS). Projections of world nuclear energy consumption are derived from nuclear power electricity generation projections from EIA's International Nuclear Model (INM), PC Version (PC-INM). All U.S. projections are taken from EIA's *Annual Energy Outlook (AEO)*.

A full description of the WEPS is provided in a model documentation report: Energy Information Administration, *World Energy Projection System Model Documentation*, DOE/EIA-M050(97) (Washington, DC, September 1997). The report presents a description of each of the spreadsheets associated with the WEPS, along with descriptions of the methodologies and assumptions used to produce the projections. The entire publication may be found through the internet in portable document format (PDF) at: ftp://ftp.eia.doe.gov/pub/pdf/model.docs/m05097.pdf.

The WEPS model will be made available for downloading through the Internet on EIA's home page by May 1999. The package will allow users to replicate the projections that appear in *IEO99*. It is coded in Excel, version 5.0, and can be executed on any IBM-compatible personal computer in a Windows environment. The package requires about 5 megabytes of hard disk space and about 640 kilobytes of random access memory (RAM).

Performance of Past *IEO* Forecasts for 1990 and 1995

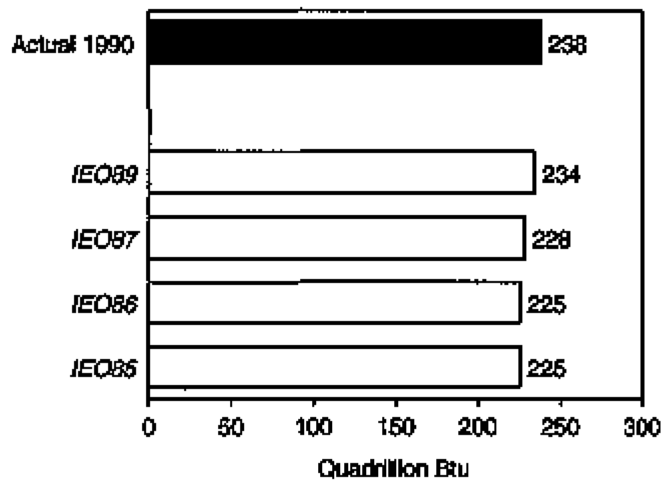
In an attempt to measure how well the *International Energy Outlook* (*IEO*) projections have estimated future energy consumption trends over its 13-year history, we present a comparison of *IEO* forecasts produced for years 1990 and 1995. The forecasts can be compared with actual data published in EIA's *International Energy Annual 1996* (*IEA96*). This comparison was undertaken as part of EIA's commitment to provide users of the *IEO* with a set of performance measures to assess the forecasts produced by this agency.[24]

EIA has published the *IEO* since 1985. In *IEO85*, mid-term projections were derived only for the world's market economies. That is, no projections were produced for the centrally planned economies (CPE) of the Soviet Union, Eastern Europe, Cambodia, China, Cuba, Laos, Mongolia, North Korea, and Vietnam. The *IEO85* projections extended to 1995 and included forecasts of total energy consumption for 1990 and 1995 and primary consumption of oil, natural gas, coal, and "other fuels." *IEO85* projections were also presented for several individual countries and subregions: the United States, Canada, Japan, the United Kingdom, France, West Germany, Italy, the Netherlands, other OECD Europe, other OECD (Australia, New Zealand, and the U.S. Territories), OPEC, and other developing countries. Beginning with *IEO86*, nuclear power projections were published separately from the "other fuel" category.

The regional aggregation has changed from report to report. In 1990, the report coverage was expanded to include projections for China, the former Soviet Union, and other CPE countries, making *IEO90* the first edition to represent the entire world in the energy consumption forecast.

The data for total regional energy consumption in 1990 show that the *IEO* projections were—with few exceptions—lower than the actual data for the market economies. For the four editions of the *IEO* printed between 1985 and 1989 (no *IEO* was published in 1988) in which 1990 projections were presented, total projected energy consumption in the market economies ran between 2 and 5 percent lower than the actual consumption number published in the *IEA96* (Figure G1).

Figure G1. Comparison of *IEO* Forecasts with 1990 Energy Consumption in Market Economies



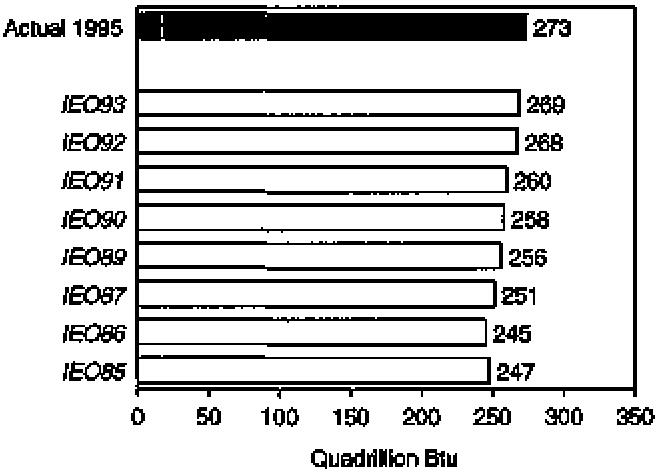
Sources: **1990:** Energy Information Administration (EIA), Office of Energy Markets and End Use, *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **1990 Projections:** EIA, *International Energy Outlook*, DOE/EIA-0484 (Washington, DC, various years).

In addition, market economy projections for 1995 in the 1985 through 1993 outlook reports (EIA did not release an international forecast for 1995 in either the 1994 or 1995 edition of the report) were consistently lower than the actual 1995 data (Figure G2). Most of the difference was for countries outside the OECD. Through the years, EIA's economic growth assumptions for OPEC and other market economy countries outside the OECD have been low. The 1993 forecast, which was, as might be expected, the closest to the actual 1995 number, still was more than 10 percent lower than the actual value.

In *IEO90*, energy consumption forecasts for the entire world were first released. Since then, the *IEO* forecasts of world energy consumption for 1995 have been consistently higher than the amount actually consumed (Figure G3), primarily because of the unanticipated collapse of the Soviet Union economies. *IEO90* projected that the FSU would consume 66 quadrillion Btu, whereas 40 quadrillion Btu of energy was actually consumed. The "other CPE" countries—driven mainly

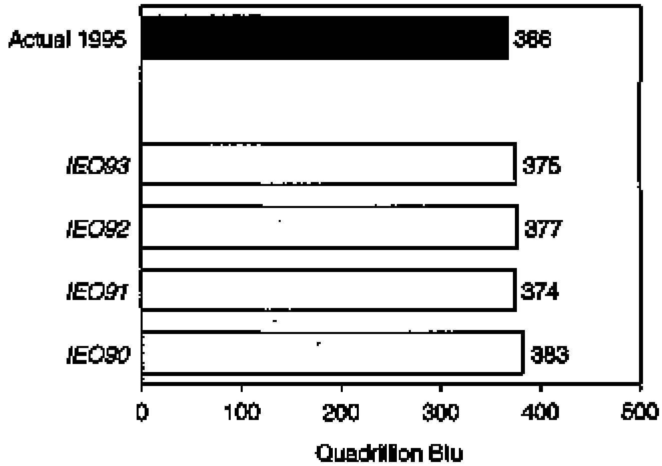
[24]For an analysis of EIA's record for world oil price forecasts, see S.H. Holte, "*Annual Energy Outlook* Forecast Evaluation," in Energy Information Administration, *Issues in Midterm Analysis and Forecasting 1997*, DOE/EIA-0607(97) (Washington, DC, July 1997), pp. 100-101.

Figure G2. Comparison of *IEO* Forecasts with 1995 Energy Consumption in Market Economies



Sources: **1995:** Energy Information Administration (EIA), Office of Energy Markets and End Use, *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **1995 Projections:** EIA, *International Energy Outlook*, DOE/EIA-0484 (Washington, DC, various years).

Figure G3. Comparison of *IEO* Forecasts with 1995 World Energy Consumption



Sources: **1995:** Energy Information Administration (EIA), Office of Energy Markets and End Use, *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **1995 Projections:** EIA, *International Energy Outlook*, DOE/EIA-0484 (Washington, DC, various years).

by consumption in the countries of Eastern Europe but also including Cambodia, Cuba, Laos, Mongolia, North Korea, and Vietnam—showed a similar pattern. The magnitude and duration of the economic declines in the FSU were not anticipated, and projections for the region ran about 30 percent higher than actual consumption.

As might be expected, the *IEO* projections for the use of specific fuels reflect the tendency of the total regional consumption projections to underestimate energy use in the market economies outside the OECD and overestimate energy use in the FSU and "other CPE." For instance, *IEO85* underestimated 1995 oil use in the "other developing market economies" by more than 40 percent, and *IEO90* overestimated 1995 oil use in the FSU by 84 percent.

It is interesting to consider the forecasts in the historical context that certainly influenced the analytical thinking of the day. For example, *IEO85*, published after the oil price shocks of the 1973-1974 Arab embargo and the 1979-1980 Iranian revolution but before the Chernobyl nuclear accident of 1986, projected that oil would lose share of total energy consumption in the market economies over the 1985-1995 decade, declining by as much as 5 percentage points as natural gas, coal, and "other fuels" all gained share. Nuclear was expected to be the fastest growing energy source, with a projected growth rate of nearly 4 percent per year.

In reality, the *IEO85* forecast for nuclear energy turned out to be fairly accurate. Nuclear power consumption did increase more rapidly than any other energy source in the market economies, at a rate of nearly 5 percent per year between 1985 and 1995. On the other hand, oil use did not decline as projected but maintained a 45-percent share of energy consumption. The natural gas share grew more slowly than projected, reaching 21 percent of energy consumption in the market economies by 1995, rather than the projected 22-percent share. The largest divergence between projected and actual trends was for coal, which in *IEO85* was expected to see increasing use for electricity generation and industrial applications in Western Europe. Those expectations did not materialize. Coal's share of energy consumption in the market economies declined from 21 percent in 1985 to 18 percent in 1995, whereas *IEO85* had projected an increase to a 22-percent share in 1995.

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