DOE/EIA-0484(2004)

International Energy Outlook 2004

April 2004

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

This publication is on the WEB at:
www.eia.doe.gov/oiaf/ieo/index.html.

Contacts

The International Energy Outlook is prepared by the Energy Information Administration (EIA). General questions concerning the contents of the report should be referred to Mary J. Hutzler (202/586-2222), Director, Office of Integrated Analysis and Forecasting, or John Conti, Director, International, Economic and Greenhouse Gases Division (202/586-4430). Specific questions about the report should be referred to Linda E. Doman (202/586-1041) or the following analysts:

World Energy Consumption	Linda Doman	(linda.doman@eia.doe.gov,	202/586-1041)
Residential Energy Use	John Cymbalsky	(john.cymbalsky@eia.doe.gov,	202/586-4815)
Commercial Energy Use	Erin Boedecker	(erin.boedecker@eia.doe.gov,	202/586-4791)
Industrial Energy Use	T. Crawford Honeycutt	(crawford.honeycutt@eia.doe.gov,	202/586-1420)
Macroeconomic Assumptions	Nasir Khilji	(nasir.khilji@eia.doe.gov,	202/586-1294)
World Oil Markets	G. Daniel Butler	(george.butler@eia.doe.gov,	202/586-9503)
Transportation Energy Demand	Aloulou Fawzi	(aloulou.fawzi@eia.doe.gov,	202/586-7818)
Natural Gas	Phyllis Martin	(phyllis.martin@eia.doe.gov,	202/586-9592)
Qatar LNG	Aloulou Fawzi	(aloulou.fawzi@eia.doe.gov,	202/586-7818)
Coal	Michael Mellish	(michael.mellish@eia.doe.gov,	202/586-2136)
Electricity	Linda Doman	(linda.doman@eia.doe.gov,	202/586-1041)
Small Wind Power	Zia Haq	(zia.haq@eia.doe.gov,	202/586-2869)
Deregulated Power Markets	James Hewlett	(james.hewlett@eia.doe.gov,	202/586-9536)
Environmental Issues	Janice Poling	(janice.poling@eia.doe.gov,	202/586-3823)

Electronic Access and Related Reports

The *IEO2004* will be available on CD-ROM and the EIA Home Page (*http://www.eia.doe.gov/oiaf/ieo/index.html*) by May 2004, including text, forecast tables, and graphics. To download the entire publication in Portable Document Format (PDF), go to *ftp://ftp.eia.doe.gov/pub/pdf/international/0484(2004).pdf*.

For ordering information and questions on other energy statistics available from EIA, please contact EIA's National Energy Information Center. Addresses, telephone numbers, and hours are as follows:

National Energy Information Center, EI-30
Energy Information Administration
Forrestal Building
Washington, DC 20585

Telephone: 202/586-8800
TTY: For people who are deaf or hard of hearing: 202/586-1181
E-mail: *infoctr@eia.doe.gov*
World Wide Web Site: *http://www.eia.doe.gov*
Gopher Site: *gopher://gopher.eia.doe.gov*

Contents

Appendixes

Tables

Appendix Tables

Appendix Tables (Continued)

Figures

Figures (Continued)

Appendix Figures

Preface

This report presents international energy projections through 2025, prepared by the Energy Information Administration, including outlooks for major energy fuels and issues related to electricity and the environment.

The *International Energy Outlook 2004* (*IEO2004*) presents an assessment by the Energy Information Administration (EIA) of the outlook for international energy markets through 2025. U.S. projections appearing in *IEO2004* are consistent with those published in EIA's *Annual Energy Outlook 2004* (*AEO2004*), which was prepared using the National Energy Modeling System (NEMS). *IEO2004* is provided as a 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 *IEO2004* projections are based on U.S. and foreign government laws in effect on October 1, 2003.

The report begins with a review of world trends in energy demand and the macroeconomic assumptions used as a major driver in deriving the projections that appear in the *IEO2004*. The historical time frame begins with data from 1970 and extends to 2001, providing readers with a 31-year historical view of energy demand. The *IEO2004* projections extend to 2025, giving readers a 24-year forecast period. New to this report is a discussion on regional end-use consumption issues in the residential, commercial, and industrial sectors.

High economic growth and low economic growth cases were developed to depict a set of alternative growth paths for the energy forecast. The two cases consider alternative growth paths for 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 indicators, including global carbon emissions, is reviewed.

The next part of the report is organized by energy source. Regional consumption projections for oil, natural gas, and coal are presented in the three fuel chapters, along with a review of the current status of each fuel on a worldwide basis. A chapter on electricity markets follows, with a review of trends for nuclear power and hydroelectricity and other marketed renewable energy resources. The report ends with a discussion of energy and environmental issues, with particular attention to the outlook for global carbon dioxide emissions.

Appendix A contains summary tables of the *IEO2004* reference case projections for world energy consumption, GDP, energy consumption by fuel, electricity consumption, carbon dioxide 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 oil, natural gas, coal, and renewable energy were prepared using EIA's System for the Analysis of Global Energy Markets (SAGE), as were projections of net electricity consumption, energy consumed by fuel for the purpose of electricity generation, and carbon dioxide emissions. In addition, the NEMS Coal Export Submodule (CES) was used to derive flows in international coal trade, presented in the coal chapter. 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. Appendix D contains summary tables of projections for world oil production capacity and oil production in the reference case and two alternative cases: high oil price and low oil price. The projections were derived from SAGE and from the U.S. Geological Survey. Appendix E contains summary tables of projections for nuclear capacity in three nuclear growth cases. Appendix F includes a set of comparisons of alternative forecasts with the *IEO2004* projections, as well as comparisons of historical *IEO* forecasts with actual historical data. Comparisons of the *IEO2004* and last year's forecast are also presented in Appendix F. Appendix G describes the SAGE model.

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

- **Industrialized Countries** (the industrialized countries contain 15 percent of the 2004 world population): **North America—**United States, Canada, and Mexico; **Western Europe—**Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom; **Industrialized Asia—**Japan, Australia, and New Zealand.
- **Eastern Europe and the Former Soviet Union (EE/FSU)** (6 percent of the 2004 world population):

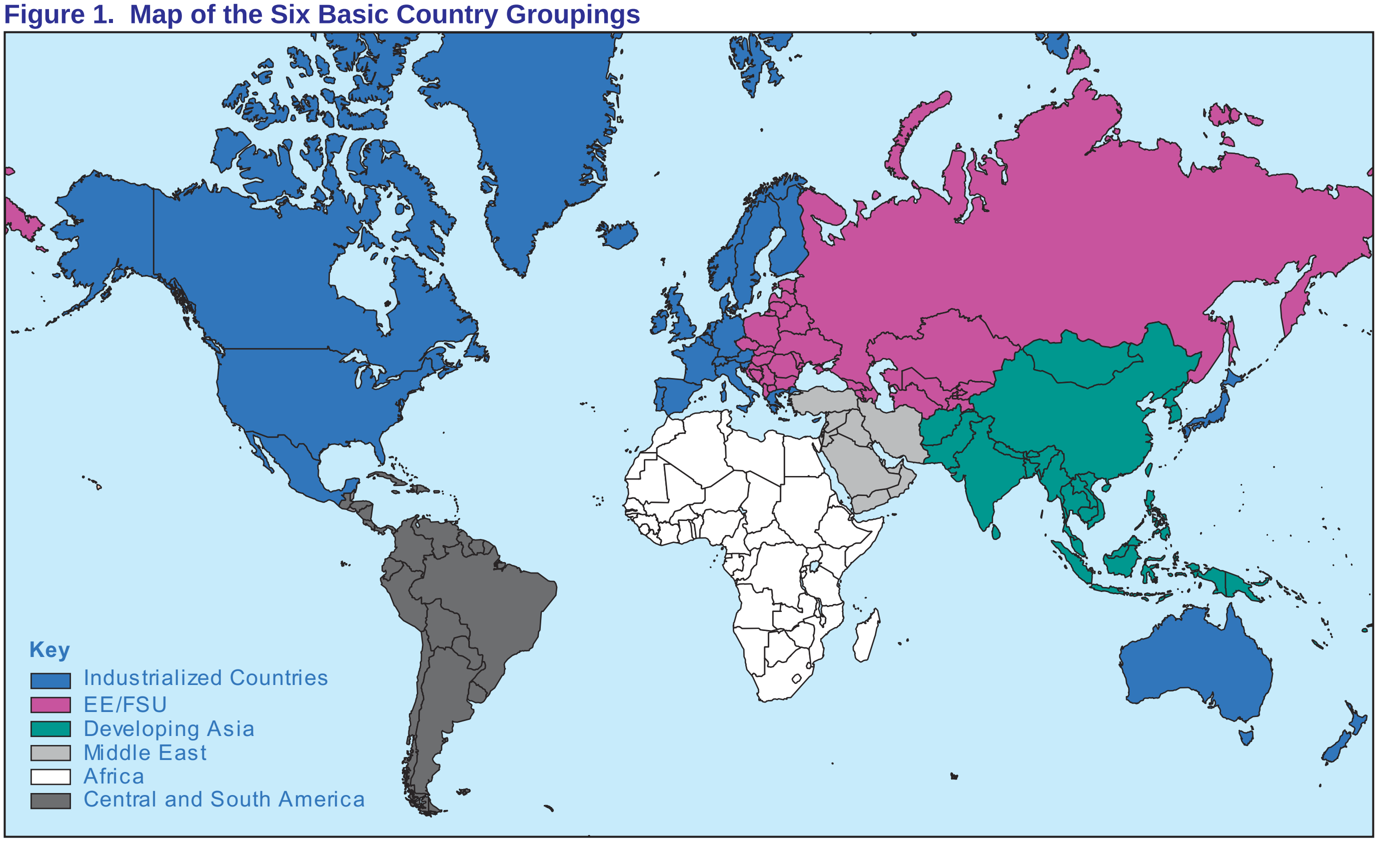
Eastern Europe—Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Hungary, Macedonia, Poland, Romania, Slovakia, Slovenia, and Yugoslavia; **Former Soviet Union—**Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Russia, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan.

- **Developing Asia** (54 percent of the 2004 world population): Afghanistan, Bangladesh, Bhutan, Brunei, Cambodia (Kampuchea), China, Fiji, French Polynesia, Guam, Hong Kong, India, Indonesia, Kiribati, 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, Vanuatu, and Vietnam.
- **Middle East** (4 percent of the 2004 world population): Bahrain, Cyprus, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, Turkey, the United Arab Emirates, and Yemen.
- **Africa** (14 percent of the 2004 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** (7 percent of the 2004 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, Puerto Rico, St. Kitts-Nevis, St. Lucia, St. Vincent/Grenadines, Suriname, Trinidad and Tobago, Turks and Caicos Islands, Uruguay, U.S. Virgin Islands, and Venezuela.

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

- **Annex I Countries** (countries participating in the Kyoto Climate Change Protocol on Greenhouse Gas Emissions): Australia, Austria, Belgium, Bulgaria,

Figure 1. Map of the Six Basic Country Groupings



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

Canada, Croatia, Czech Republic, Denmark, Estonia, European Community, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein, Lithuania, Luxembourg, Monaco, the Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, and the United Kingdom.[1]

- **European Union (EU):** Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden, and the United Kingdom.
- **G8:** Canada, France, Germany, Italy, Japan, Russia, United Kingdom, and the United States.
- **North American Free Trade Agreement (NAFTA) Member Countries:** Canada, Mexico, and the United States.
- **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, Slovakia, South Korea, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States.
- **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.

Objectives of the *IEO2004* Projections

The projections in *IEO2004* 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 U.S. and foreign government laws effective as of October 1, 2003. Assuming fixed laws, 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 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. In 2001, the United States withdrew from the Protocol, and Kazakhstan requested that it be added to the list of Annex I countries.

Highlights

World energy consumption is projected to increase by 54 percent from 2001 to 2025. Much of the growth in worldwide energy use is expected in the developing world in the IEO2004 reference case forecast.

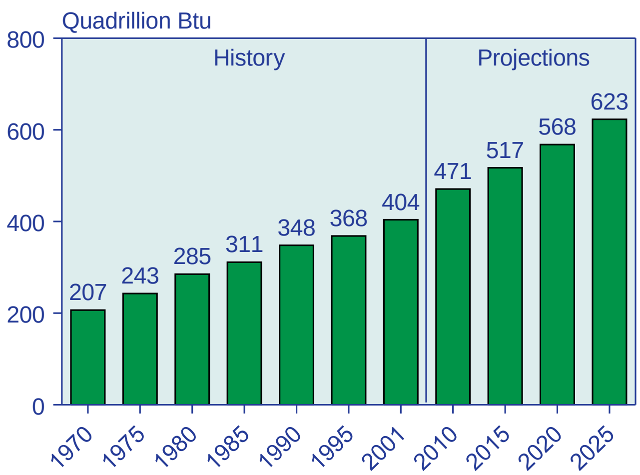
In the *International Energy Outlook 2004* (*IEO2004*) reference case, world marketed energy consumption is projected to increase by 54 percent over the 24-year forecast horizon from 2001 to 2025. Worldwide, total energy use is projected to grow from 404 quadrillion British thermal units (Btu) in 2001 to 623 quadrillion Btu in 2025 (Figure 2).

The *IEO2004* reference case outlook shows strongest growth in energy consumption among the developing nations of the world, as it has in past editions of this report (Figure 3). The fastest growth is projected for the nations of developing Asia, including China and India, where robust economic growth accompanies the increase in energy consumption over the forecast period. Gross domestic product (GDP) in developing Asia is expected to expand at an average annual rate of 5.1 percent, compared with 3.0 percent per year for the world as a whole. With such strong growth in GDP, demand for energy in developing Asia doubles over the forecast, accounting for 40 percent of the total projected increment in world energy consumption and 70 percent of the increment for the developing world alone.

In contrast to the developing world, slower growth in energy demand is projected for the industrialized world, averaging 1.2 percent per year over the forecast period. Generally, the nations of the industrialized world can be characterized as mature energy consumers with comparatively slow population growth. Gains in energy efficiency and movement away from energy-intensive manufacturing to service industries result in the lower growth in energy consumption. In the transitional economies of Eastern Europe and the former Soviet Union (EE/FSU) energy demand is projected to grow by 1.5 percent per year in the *IEO2004* reference case. Slow or declining population growth in this region, combined with strong projected gains in energy efficiency as old, inefficient equipment is replaced, leads to the projection of more modest growth in energy use than in the developing world.

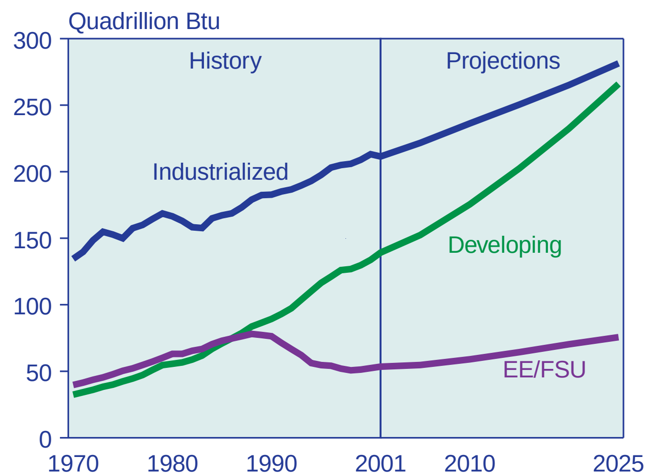
World oil prices rose by almost $10 per barrel over the course of 2002 and remained high throughout 2003. Prices were influenced by political unrest in Venezuela and Nigeria, the war in Iraq, and the continued discipline of producers in the Organization of Petroleum Exporting Countries (OPEC) in adhering to production cutbacks. The *IEO2004* reference case expects little downward movement in world oil prices in 2004, given low oil inventories, a surge in developing Asia's oil

Figure 2. World Marketed Energy Consumption, 1970-2025



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

Figure 3. World Marketed Energy Consumption by Region, 1970-2025



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

demand, and the regional uncertainty that surrounds the situation in Iraq. The world oil price path in the reference case is virtually the same as in last year's forecast, with prices projected to moderate after 2004 and then rise slowly to 2025 (Figure 4). World oil prices are projected to reach $27 per barrel in 2002 dollars ($51 per barrel in nominal dollars) at the end of the forecast period. These prices are average annual prices and exclude the volatility that may occur as a result of weather variations or possible disruptions in supply.

Outlook for World Energy Demand

The *IEO2004* reference case projects increased consumption of all primary energy sources over the 2001-2025 period (Figure 5). Fossil fuel prices for electricity production are projected to remain low relative to the costs of nuclear power and renewable energy sources; as a result, non-fossil fuels are not expected to be economically competitive with fossil fuels over the forecast. The outlook for fossil fuels could, however, be altered by government policies or programs, such as environmental laws aimed at limiting or reducing pollutants from the combustion of fossil fuel consumption and encouraging the use of non-fossil fuels. In the absence of such laws, consumption of oil, natural gas, and coal is expected to supply most of the primary energy needed to meet the projected demand for end-use consumption.

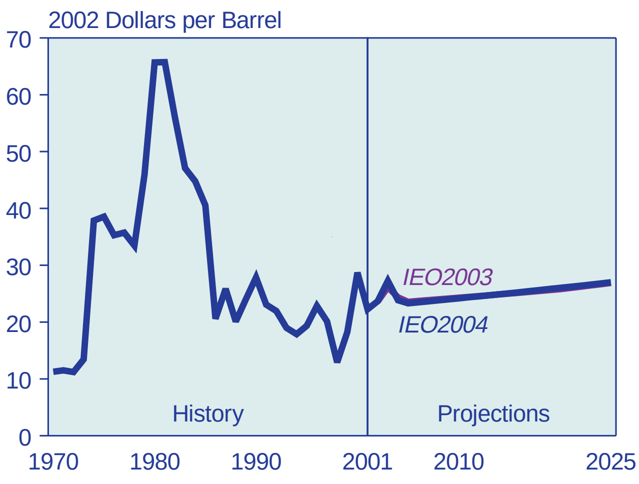
Oil is expected to remain the dominant energy source worldwide through 2025. In the *IEO2004* reference case, world oil demand increases by 1.9 percent annually over the 24-year projection period, from 77 million barrels per day in 2001 to 121 million barrels per day in 2025. Much of the increase in oil demand is projected to occur in the United States and in developing Asia. The United States, China, and the other nations of developing Asia account for nearly 60 percent of the increment in world oil demand in the *IEO2004* reference case.

The projected increment in worldwide oil use would require an increment to world productive capacity of more than 44 million barrels per day over current levels. Although OPEC producers are expected to be the major suppliers of increased production requirements, non-OPEC supply is expected to remain competitive, with major increments in supply coming from offshore resources, especially in the Caspian Basin, Latin America, and deepwater West Africa.

Over the past several decades, oil has been the world's foremost source of primary energy consumption, and it is expected to remain in that position throughout the 2001 to 2025 period. Oil's share of world energy is maintained throughout the forecast, at 39 percent, despite expectations that countries in many parts of the world will be switching from oil to natural gas and other fuels for their electricity generation (Figure 6). Robust growth in transportation energy use—overwhelmingly fueled by petroleum products—is expected to continue over the 24-year forecast period. As a result, oil is projected to retain its predominance in the global energy mix, notwithstanding increases in the penetration of new technologies such as hydrogen-fueled vehicles.

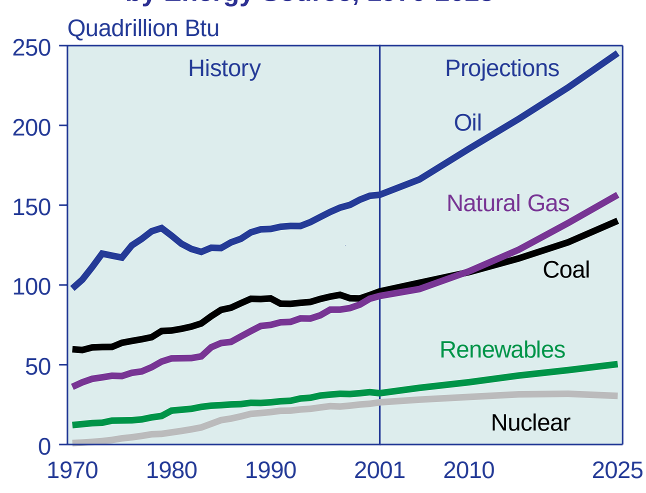
Although the nations of the industrialized world continue to consume more of the world's petroleum products than do those of the developing world, the gap is

Figure 4. Comparison of 2003 and 2004 World Oil Price Projections, 1970-2025



Sources: **History:** Energy Information Administration (EIA), *Annual Energy Review 2002*, DOE/EIA-0384(2002) (Washington, DC, October 2003), web site www.eia.doe.gov/emeu/aer/contents.html. **IEO2003:** EIA, *International Energy Outlook 2003*, DOE/EIA-0484(2003) (Washington, DC, May 2003), web site www.eia.doe.gov/oiaf/ieo/index.html. **IEO2004:** EIA, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), web site www.eia.doe.gov/oiaf/aeo/index.html.

Figure 5. World Marketed Energy Consumption by Energy Source, 1970-2025

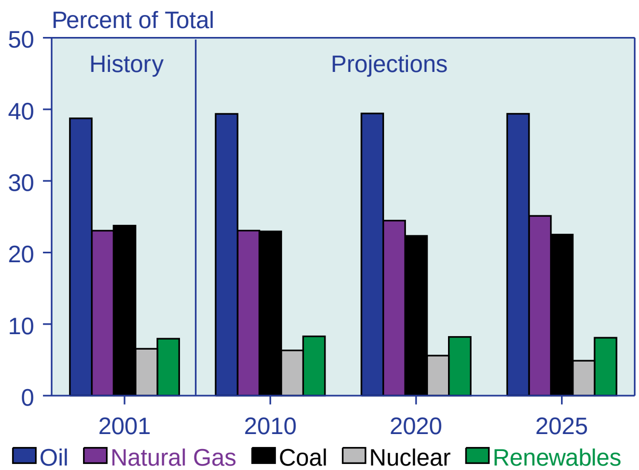


Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

projected to narrow considerably over the forecast period. In 2001, developing nations consumed about two-thirds (64 percent) as much oil as the industrialized nations; by 2025 they are expected to consume 94 percent as much as the industrialized nations. In the industrialized world, increases in oil use are expected mainly in the transportation sector, where there are few economically competitive alternatives at present. In the developing world, oil demand is projected to grow in all end-use sectors. As the energy infrastructures of emerging economies improve, people are turning from traditional fuels for residential and commercial uses—such as wood burning for heating and cooking—to diesel-fired electricity, and industrial demand for petrochemical feedstocks is increasing.

The fastest growing source of primary energy in the *IEO2004* reference case is natural gas. Over the 2001-2025 forecast period, consumption of natural gas is projected to increase by 67 percent in the reference case, to 151 trillion cubic feet in 2025. The projection for natural gas consumption is lower than in last year's report, which showed worldwide demand for gas at 176 trillion cubic feet in 2025 (Figure 7). The lower forecast this year is the result of slightly lower assumptions for worldwide economic growth, a slower projected decline in nuclear power generation (which competes with natural gas in the power sector), and concerns about the long-term ability of natural gas producers to bring sufficient resources to market at prices competitive with those of other fuels. Natural gas use is expected to equal coal use (on a Btu basis) by 2010, and by 2025 it is expected to exceed coal use by 12 percent (Figure 5).

Figure 6. World Energy Consumption Shares by Fuel Type, 2001, 2010, 2020, and 2025



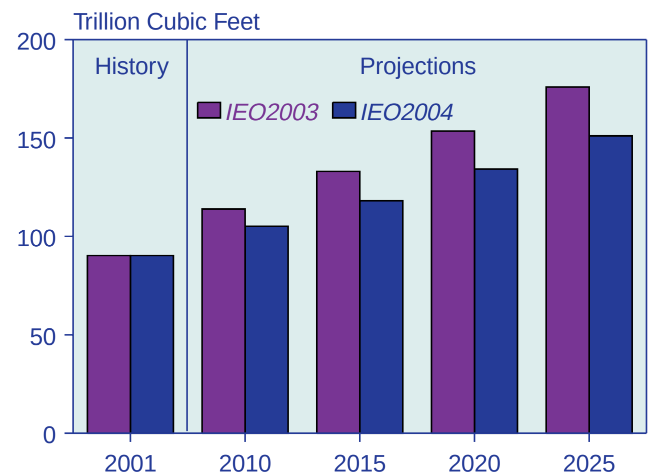
Sources: **2001:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

Natural gas is expected to remain an important supply source for new electric power generation in the future. It is seen as the desired option for electric power, given its relative efficiency and environmental advantages in comparison with other fossil energy sources. Natural gas burns more cleanly than either coal or oil, making it a more attractive choice for countries seeking to reduce greenhouse gas emissions.

The growing importance of natural gas in the electric power sector is more pronounced in the industrialized and EE/FSU regions than in the developing world. In the industrialized nations and the EE/FSU, for the most part the natural gas infrastructure is considered mature, and the gas share of total electricity generation is projected to grow from 20 percent in 2001 to 30 percent in 2025. In the developing world, the natural gas infrastructure has not yet been as widely established. As a result, the projected increase in the natural gas share of total generation in the developing world is smaller—from 14 percent in 2001 to 17 percent in 2025.

Coal remains an important fuel in the world's electricity markets and is expected to continue to dominate energy markets in developing Asia. World coal use has been in a period of generally slow growth since the 1980s, and that trend is expected to continue through the projection period. With the projected growth in coal consumption averaging 1.5 percent per year through 2025, coal's share of total world energy consumption declines slightly in the *IEO2004* reference case forecast, from 24 percent in 2001 to 23 percent in 2025.

Figure 7. Comparison of 2003 and 2004 Projections for World Natural Gas Consumption, 2001, 2010, 2020, and 2025



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. ***IEO2003:*** EIA, *International Energy Outlook 2003*, DOE/EIA-0484(2003) (Washington, DC, March 2003), web site www.eia.doe.gov/oiaf/ieo/index.html. ***IEO2004:*** EIA, System for the Analysis of Global Energy Markets (2004).

Coal use is projected to increase in all regions except for Western Europe and the EE/FSU (excluding Russia), where coal is expected to be displaced by natural gas and, in the case of France, nuclear power for electric power generation. Large increments in coal use are projected for developing Asia, especially in China and India. As very large countries in terms of both population and land mass, and with ample domestic coal resources, China and India are projected to account for 67 percent of the total increase in coal use worldwide (on a Btu basis).

Currently, of the coal consumed worldwide, 64 percent is used for electricity generation; and in almost every region, power generation accounts for most of the projected growth in coal consumption. Significant amounts of coal are also used for steel production. Where coal is used in the industrial, residential, and commercial sectors, other energy sources—primarily, natural gas—are expected to gain market share. One exception is China. With China's abundant coal reserves and limited access to other sources of energy, coal continues to be the most widely used fuel in the country's rapidly growing industrial sector. 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 replacement of steel by other materials in end-use applications.

Over the projection period, worldwide net electricity consumption is projected to nearly double between 2001 and 2025, from 13,290 billion kilowatthours to 23,072 billion kilowatthours. Strong growth in electricity use is expected in the countries of the developing world, where electricity demand increases by an average of 3.5 percent per year in the *IEO2004* reference case, compared with a projected average increase of 2.3 percent per year worldwide. Robust economic growth in many of the developing nations is expected to boost demand for electricity to run newly purchased home appliances for air conditioning, cooking, space and water heating, and refrigeration. For the industrialized world and the transitional economies of the EE/FSU, where electricity markets are more mature, slower average growth rates of 1.6 percent per year and 2.0 percent per year, respectively, are projected.

Worldwide, electricity generation from nuclear power is projected to increase from 2,521 billion kilowatthours in 2001 to 3,032 billion kilowatthours in 2020, before declining slightly to 2,906 billion in 2025. The nuclear power forecast is higher than in last year's outlook, because the prospects for nuclear power have been reassessed in light of higher capacity utilization rates reported for many existing nuclear facilities and the expectation that fewer retirements of existing plants will occur than previously projected. Extensions of operating licenses (or the equivalent) for nuclear power plants are expected to be granted among the countries of the industrialized world, slowing the decline in nuclear generation. In the United States, natural gas prices are projected to be higher than in previous forecasts, and as a result no U.S. nuclear power units are expected to be retired in the *IEO2004* reference case.

The largest increase in nuclear generation is expected for the developing world, where consumption of electricity from nuclear power increases by an average of 4.1 percent per year from 2001 to 2025 in the reference case. In particular, developing Asia is expected to see the greatest increase in worldwide nuclear generating capacity, accounting for 96 percent of the total projected increment in nuclear capacity in the developing world. Of the 44 gigawatts of additional installed nuclear generating capacity projected for developing Asia, 19 gigawatts is projected for China, 15 gigawatts for South Korea, and 6 gigawatts for India.

In the *IEO2004* reference case, moderate growth in the world's consumption of hydroelectricity and other renewable energy resources is projected over the next 24 years, averaging 1.9 percent per year in the *IEO2004* reference case. Much of the projected growth in renewable generation is expected to result from the completion of large hydroelectric facilities in developing countries, particularly in developing Asia. China, India, and other developing Asian countries are constructing or planning new, large-scale hydroelectric facilities. Among the industrialized nations, only Canada has plans to construct any sizable hydroelectric projects over the forecast period. Much of the expected increment in renewable energy consumption in the industrialized world is projected to be nonhydropower renewables, including particularly wind energy in Western Europe and the United States. In addition, biomass and geothermal energy sources are expected to grow rapidly in the United States.

Carbon Dioxide Emissions

Carbon dioxide is one of the most prevalent greenhouse gases in the atmosphere. Anthropogenic emissions of carbon dioxide result primarily from the combustion of fossil fuels for energy use, and as a result world energy use has emerged at the center of the climate change debate. In the *IEO2004* reference case, world carbon dioxide emissions are projected to rise from 23.9 billion metric tons in 2001 to 27.7 billion metric tons in 2010 and 37.1 billion metric tons in 2025 (Figure 8).[2]

[2]In keeping with current international practice, *IEO2004* presents data on carbon dioxide emissions in million metric tons carbon dioxide equivalent. The figures can be converted to carbon equivalent units by multiplying by 12/44.

Much of the projected increase in carbon dioxide emissions is expected in the developing world (Figure 9), accompanying the large increases in energy use projected for the region's emerging economies. Developing countries account for 61 percent of the projected increment in carbon dioxide emissions between 2001 and 2025. Continued heavy reliance on coal and other fossil fuels, as projected for the developing countries, would ensure that even if the industrialized world undertook efforts to reduce carbon dioxide emissions, there still would be substantial increases in worldwide carbon dioxide emissions over the forecast horizon.

Energy Intensity

Energy intensity (that is, the relationship between energy consumption and growth in gross domestic product) is an important factor that affects changes in energy consumption over time. In the industrialized countries, history shows the link between energy consumption and economic growth to be a relatively weak one, with growth in energy demand lagging behind economic growth. In the developing countries, the two have been more closely correlated, with energy demand growing in parallel with economic expansion.

In the *IEO2004* forecast, energy intensity in the industrialized countries is expected to improve (decrease) by an average of 1.2 percent per year between 2001 and 2025, slightly slower than the 1.4 percent per year improvement for the region between 1970 and 2001. Energy intensity is expected to improve more rapidly in the developing countries—by 1.8 percent per year on average—as their economies begin to behave more like those of the industrialized countries as a result of the improvement in standards of living expected to accompany projected economic expansion (Figure 10).

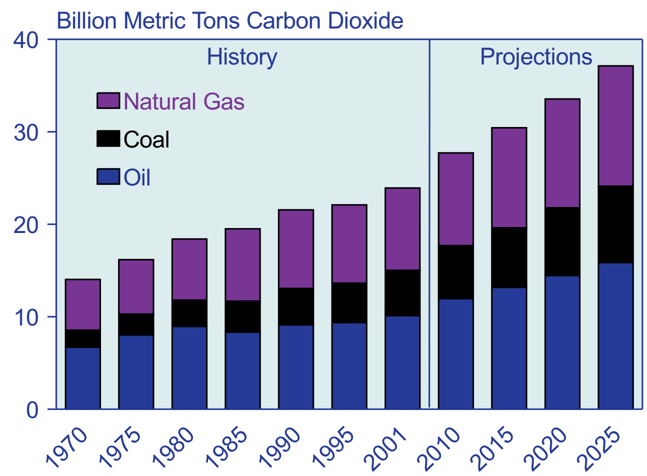
For more than three decades, the EE/FSU has maintained a much higher level of energy intensity than either the industrialized or developing countries. Over the forecast horizon the region's energy intensity is expected to improve—by 2.5 percent per year on average—in concert with expected recovery from the economic and social declines of the early 1990s; however, it is still expected to be twice as high as in the developing world and five times as high as in the industrialized world.

Carbon Dioxide Intensity

World carbon dioxide intensity has improved (decreased) substantially over the past three decades, falling from 1,100 metric tons per million 1997 dollars of GDP in 1970 to 739 metric tons per million 1997 dollars in 2001. Although the pace of improvement in emissions intensity is expected to slow over the forecast period, a continuing decline is projected in the reference case, to 566 metric tons per million 1997 dollars of GDP in 2025.

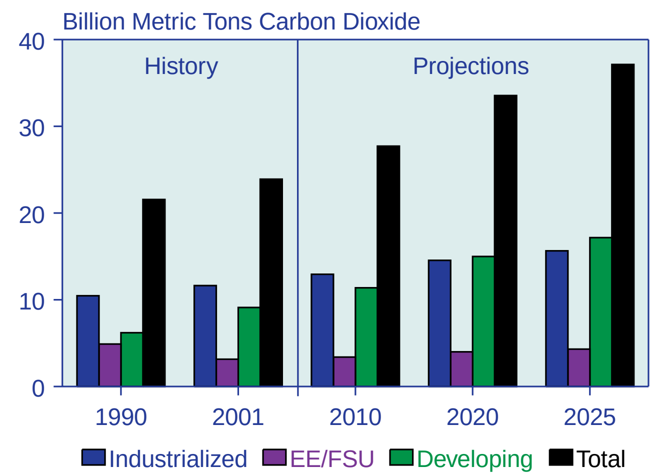
On a regional basis, the most rapid rates of improvement in carbon dioxide intensity are projected for the transitional economies of the EE/FSU and for China. In the FSU, economic recovery from the upheaval of the 1990s is expected to continue throughout the forecast. The FSU nations are also expected to replace old and inefficient capital stock as economic recovery progresses. Eastern European nations began their economic recovery much earlier than the nations of the former Soviet Union. As a result of strong investment in improving the efficiency

Figure 8. World Carbon Dioxide Emissions by Fossil Fuel, 1970-2025



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

Figure 9. World Carbon Dioxide Emissions by Region, 1990-2025



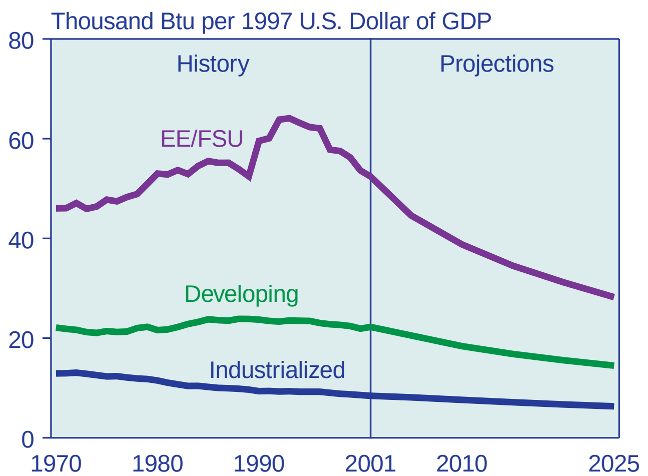
Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

of energy use among Eastern European countries and a push to increase the use of natural gas, carbon dioxide intensity fell by nearly 40 percent in Eastern Europe between 1990 and 2001, as compared with only 5 percent in Russia and 9 percent in the other FSU nations. Improvement in carbon dioxide intensity in Eastern Europe is projected to continue over the projection period, at an average rate of 2.9 percent per year (Figure 11).

Developing Asia is expected to see fairly rapid improvement in carbon dioxide intensity over the 2001-2025 period, primarily as a result of rapid economic growth, rather than a switch to less carbon-intensive fuels. China, in particular, is expected to remain heavily reliant on fossil fuels, especially coal, in the *IEO2004* reference case, but its annual GDP growth is projected to average 6.1 percent, compared with an expected 3.4-percent annual rate of increase in fossil fuel use over the projection period. China's carbon dioxide intensity is expected to decrease by 2.6 percent per year on average between 2001 and 2025.

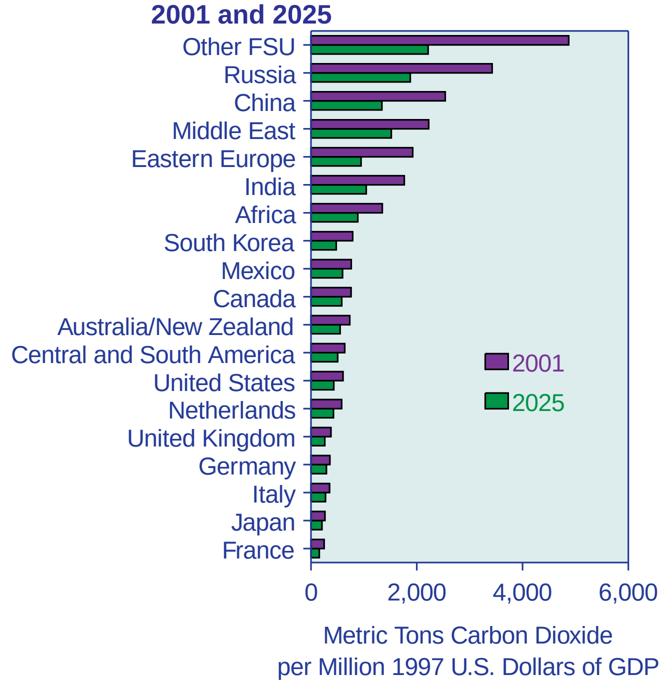
Rates of improvement in carbon dioxide intensity could vary considerably in the future, based on technological advances, government policy initiatives, and economic growth rates. In the *IEO2004* reference case, world carbon dioxide intensity is projected to fall from 739 metric tons per million 1997 dollars of GDP in 2001 to 566 metric tons per million dollars in 2025; however, if world economic growth expanded to the levels projected in the *IEO2004* high economic growth case, carbon dioxide intensity could fall more quickly, to 558 metric tons per million dollars in 2025. In contrast, if world GDP expanded more slowly, as in the low economic growth case, world carbon dioxide intensity would decline to a projected 575 metric tons per million dollars in 2025.

Figure 10. World Energy Intensity by Region, 1970-2020



Sources: **History:** Derived from Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

Figure 11. World Carbon Dioxide Intensity by Selected Countries and Regions, 2001 and 2025



Sources: **2001:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **2025:** EIA, System for the Analysis of Global Energy Markets (2004).

World Energy and Economic Outlook

The IEO2004 projections indicate continued growth in world energy use, including large increases for the developing economies of Asia. Energy resources are thought to be adequate to support the growth expected through 2025.

The *International Energy Outlook 2004* (*IEO2004*) projects strong growth for worldwide energy demand over the 24-year projection period from 2001 to 2025. Total world consumption of marketed energy[3] is expected to expand by 54 percent, from 404 quadrillion British thermal units (Btu) in 2001 to 623 quadrillion Btu in 2025 (Table 1 and Figure 12).

In the *IEO2004* mid-term outlook, developing nations of the world are largely expected to account for the increment in world energy consumption. In particular, energy demand in the emerging economies of developing Asia, which include China and India, is projected to more than double over the next quarter century. In the developing world as a whole, primary energy consumption is projected to grow at an average annual rate of 2.7 percent between 2001 and 2025 (Figure 13). In contrast, in the industrialized world—with its more mature energy-consuming nations—energy use is expected to grow at a much slower rate of 1.2 percent per year over the same period, and in the transitional economies of Eastern Europe and the former Soviet Union (EE/FSU) growth in energy demand is projected to average 1.5 percent per year.

This chapter begins with an overview of the *IEO2004* outlook for energy consumption by primary energy source. In addition, in order to give readers some perspective about the ways in which energy sources are currently used and how energy use may evolve in the future, a discussion of trends in energy consumption in the residential, commercial, and industrial sectors is also presented. The chapter continues with the outlook for world carbon dioxide emissions resulting from the combustion of fossil fuels. The next section of the chapter discusses of the macroeconomic forecast in the context of recent economic developments in key nations of the industrialized world, the EE/FSU region, and the developing world.

As with any set of forecasts, there is uncertainty associated with the *IEO2004* energy projections. Consequently, the next section of the chapter looks at issues surrounding the forecast uncertainty, including a look at some of the elements that drive the *IEO2004* projections, which can result in a fair amount of variation in a forecast. Alternative assumptions about economic growth and their impacts on the *IEO2004* projections are considered, as well as the possible effects of future trends in energy intensity on the reference case projections.

Outlook for Primary Energy Consumption

The *IEO2004* reference case projects increased consumption of all primary energy sources over the 24-year forecast horizon (Figure 14 and Appendix A, Table A2). With fossil fuel prices projected to remain relatively low,

Table 1. World Energy Consumption and Carbon Dioxide Emissions by Region, 1990-2025

Region	Energy Consumption (Quadrillion Btu)				Carbon Dioxide Emissions (Million Metric Tons)			
	1990	2001	2010	2025	1990	2001	2010	2025
Industrialized Countries	**182.8**	**211.5**	**236.3**	**281.4**	**10,462**	**11,634**	**12,938**	**15,643**
EE/FSU	**76.3**	**53.3**	**59.0**	**75.6**	**4,902**	**3,148**	**3,397**	**4,313**
Developing Countries	**89.3**	**139.2**	**175.5**	**265.9**	**6,200**	**9,118**	**11,379**	**17,168**
Asia	52.5	85.0	110.6	173.4	3,994	6,012	7,647	11,801
Middle East	13.1	20.8	25.0	34.1	846	1,299	1,566	2,110
Africa	9.3	12.4	14.6	21.5	656	843	971	1,413
Central and South America	14.4	20.9	25.4	36.9	703	964	1,194	1,845
Total World	**348.4**	**403.9**	**470.8**	**622.9**	**21,563**	**23,899**	**27,715**	**37,124**

Sources: **1990 and 2001:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **2010 and 2025:** EIA, System for the Analysis of Global Energy Markets (2004).

[3]Throughout this report, projections of energy consumption include only marketed (i.e., commercially traded) sources of energy.

the costs of generating energy from other fuels are not expected to become competitive; as a result, much of the increment in future energy demand in the reference case is projected to be supplied by oil, natural gas, and coal. It is possible, however, that as environmental programs or government policies—particularly those designed to limit or reduce greenhouse gas emissions, such as the Kyoto Protocol[4]—are implemented, the outlook could change, and non-fossil fuels (including nuclear power and renewable energy sources such as hydroelectricity, geothermal, biomass, solar, and wind power) could become more attractive. The *IEO2004* projections assume that government laws in place as of October 1, 2003, remain unchanged over the forecast horizon.

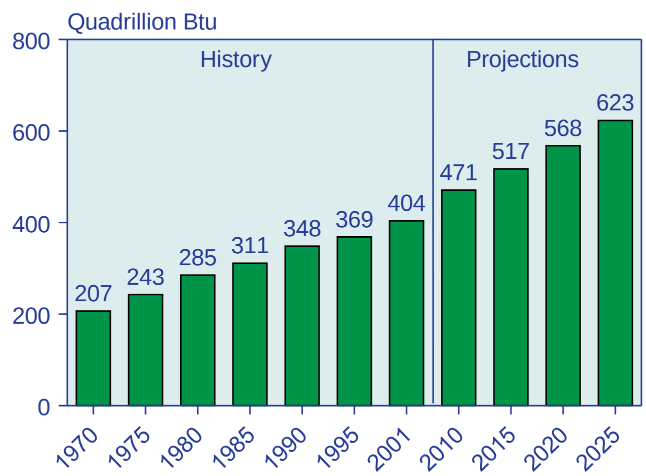
Oil is expected to remain the dominant energy fuel throughout the forecast period, with its share of total world energy consumption remaining unchanged at 39 percent through 2025. In the industrialized world, increases in oil use are projected primarily in the transportation sector, where there are currently no available fuels to compete significantly with oil products. The *IEO2004* reference case projects declining oil use for electricity generation, with other fuels (especially natural gas) expected to provide more favorable alternatives to oil-fired generation.

In the developing world, oil consumption is projected to increase for all end uses. In some countries where non-marketed fuels have been widely used in the past (such as fuel wood for cooking and home heating), diesel generators (as well as distributed generators, such as solar photovoltaics) are now sometimes being used to dissuade rural populations from decimating surrounding forests and vegetation—most notably, in Sub-Saharan Africa, Central and South America, and Southeast Asia [***1***]. Because the infrastructure necessary to expand natural gas use has not been as widely established in the developing world as it has in the industrialized world, natural gas use is not expected to grow enough in the developing world to accommodate all of the increased demand for energy.

Natural gas is projected to be the fastest growing primary energy source worldwide, maintaining average growth of 2.2 percent annually over the 2001-2025 period. In comparison, 1.9-percent average annual growth rates are projected for oil and for renewables, 1.6-percent annual growth is projected for coal, and 0.6-percent annual growth is projected for nuclear power (on a Btu basis). Total world natural gas consumption is projected to rise from 90 trillion cubic feet in 2001 to 151 trillion cubic feet in 2025, as compared with the forecast of 176 trillion cubic feet in 2025 in EIA's *International Energy Outlook 2003* (Figure 15). The reduction is a result of a combination of factors, including slightly lower assumptions about worldwide economic growth in the forecast, a slower decline projected for nuclear power generation, which competes with natural gas in the electric power sector, and concerns about the long-term ability of natural gas producers to bring sufficient resources to market at prices competitive with those of other fossil fuels.

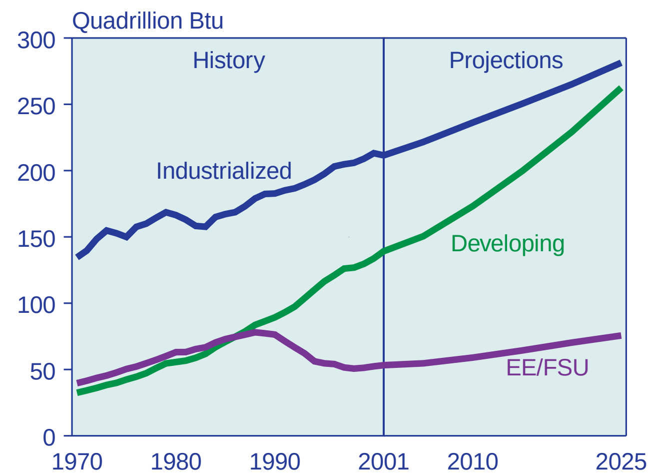
Natural gas is expected to remain an important supply source for new electric power generation in the forecast.

Figure 12. World Primary Energy Consumption, 1970-2025



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

Figure 13. World Energy Consumption by Region, 1970-2025



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

[4]In *IEO2004*, the Kyoto Protocol is assumed not to be enacted, because it had not been ratified by the required number of nations as of October 1, 2003. For further discussion of the Protocol, see the chapter on "Environmental Issues and World Energy Use."

It is seen as the desired option for electric power, given its efficiency relative to other energy sources and the fact that it burns more cleanly than either coal or oil, making it a more attractive choice for countries interested in reducing greenhouse gas emissions. In the United States, the industrial sector is expected to remain the largest end-use consumer of natural gas, growing by 1.4 percent per year on average, from 7.3 trillion cubic feet in 2001 to 10.3 trillion cubic feet in 2025. In the electric power sector, natural gas use is projected to increase by 1.9 percent per year, from 5.4 trillion cubic feet to 8.4 trillion cubic feet.

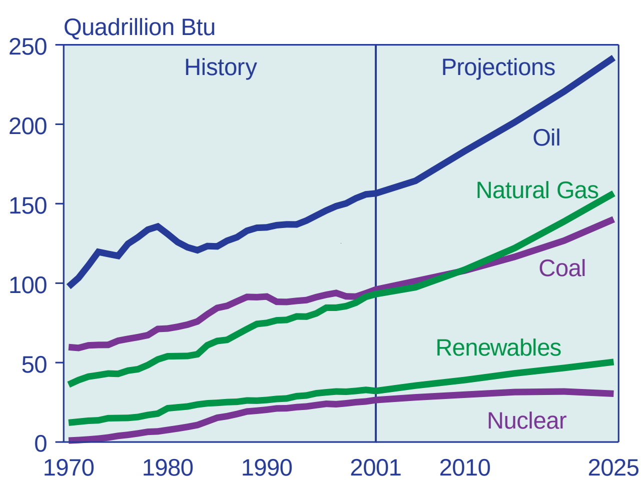
Coal use worldwide is projected to increase by 2.3 billion short tons between 2001 and 2025. Substantial declines in coal use are projected for Western Europe and Eastern Europe, where natural gas is increasingly being used to fuel new growth in electric power generation and for other uses in the industrial and building sectors. In the developing world, however, larger increases in coal use are projected for China and India, where coal supplies are plentiful. Together, China and India account for 85 percent of the projected rise in coal use in the developing world and 70 percent of the total world increment in coal demand over the forecast period.

Electricity generation is expected to nearly double between 2001 and 2025, from 13,290 billion kilowatthours to 23,702 billion kilowatthours. Strongest growth is projected for the countries of the developing world, where net electricity consumption rises by 3.5 percent per year in the *IEO2004* reference case, compared with a projected average increase of 2.3 percent per year worldwide. Robust economic growth in many of the developing nations is expected to boost demand for electricity to run newly purchased home appliances for air conditioning, cooking, space and water heating, and refrigeration. For the industrialized world and the transitional economies of the EE/FSU, where electricity markets are more mature, more modest annual growth rates of 1.5 and 2.0 percent, respectively, are projected.

As noted above, natural gas is expected to be the fuel of choice for much of the new electricity generation capacity built over the next two decades. The natural gas share of total energy used to generate electricity increases from 18 percent in 2001 to 25 percent in 2025, at the expense of oil and nuclear power, both of which are expected to lose market share of the world's electricity by 2025. The shares of hydroelectricity and other renewable energy resources, as well as that of coal use for electricity generation, are expected to remain fairly stable over the projection period.

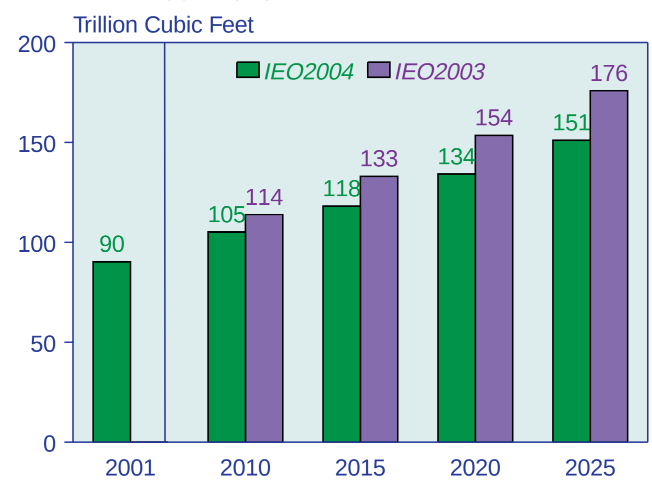
Worldwide, consumption of electricity generated from nuclear power is expected to increase from 2,521 billion kilowatthours in 2001 to 2,906 billion kilowatthours in 2025. The nuclear power forecast is somewhat higher than in last year's *IEO.* The prospects for nuclear power have been reassessed in light of the higher capacity utilization rates reported for many existing nuclear facilities and the expectation that fewer retirements of existing plants will occur than previously projected. Extensions of operating licenses (or the equivalent) for nuclear power plants are expected to be granted among the countries of the industrialized world and the EE/FSU, slowing the decline in nuclear generation. With higher

Figure 14. World Primary Energy Consumption by Energy Source, 1970-2025



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

Figure 15. World Natural Gas Consumption, 2001-2025



Sources: **2001:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. ***IEO2003:*** EIA, *International Energy Outlook 2003*, DOE/EIA-0484(2003) (Washington, DC, May 2003). ***IEO2004:*** EIA, System for the Analysis of Global Energy Markets (2004).

projections for natural gas prices in the United States than have been expected in earlier years, no U.S. nuclear power units are retired in the reference case.

The world nuclear generation forecast also reflects revised prospects for new construction of nuclear plants in several countries, in terms of both earlier completion dates and the number of new units that may be constructed. In the *IEO2004* reference case, world nuclear capacity is projected to rise from 353 gigawatts in 2001 to 407 gigawatts in 2015 before falling to 385 gigawatts in 2025 (Figure 16). In contrast, in last year's *IEO*, world nuclear capacity was projected to rise to 393 gigawatts in 2015 and then fall to 366 gigawatts in 2025.

The highest growth in nuclear generation is expected for the developing world, where consumption of electricity from nuclear power is projected to increase by 4.1 percent per year between 2001 and 2025. Developing Asia, in particular, is expected to see the largest increment in installed nuclear generating capacity over the forecast, accounting for 95 percent of the total increase in nuclear power capacity for the developing world. Of the 44 gigawatts of additional installed nuclear generating capacity projected for developing Asia, 19 gigawatts is projected for China, 15 gigawatts for South Korea, and 6 gigawatts for India.

Consumption of electricity from hydropower and other renewable energy sources is projected to grow by 1.9 percent annually in the *IEO2004* forecast. With fossil fuel prices projected to remain moderate in the reference case, renewable energy sources are not expected to be widely competitive, and the renewable share of total energy use is not expected to increase. Over the 2001-2025 forecast horizon, renewables maintain their share of total energy consumption at 8 percent. Moreover, despite the high rates of growth projected for alternative renewable energy sources—such as wind power in Western Europe and the United States—much of the growth in renewable energy sources is expected to result from large-scale hydroelectric power projects in the developing world, particularly among the nations of developing Asia. China, India, Malaysia, and Vietnam are already constructing or have plans to construct ambitious hydroelectric projects in the coming decades.

Energy End Use

One way of looking at the future of world energy markets is to consider trends in energy consumption at the end-use sector level. With the exception of the transportation sector, which is almost universally dominated by petroleum products (and is discussed separately in the chapter on "World Oil Markets"), the mix of energy use in the residential, commercial, and industrial sectors can vary widely from country to country, depending on a combination of regional factors, such as the availability of energy resources, the level of economic development, and political and social factors. Regional trends in energy end use are discussed below.

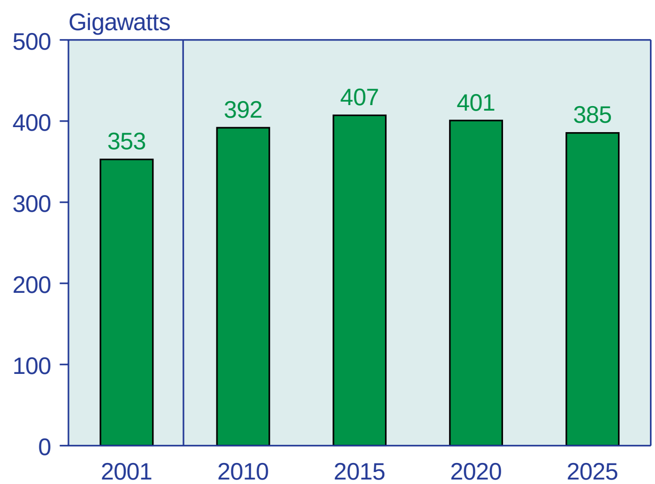
Residential Sector

Energy end use in the residential sector is defined as energy consumed by households, excluding transportation uses. The type and amount of energy used by households varies from country to country, depending on income levels, natural resources, and available energy infrastructure. In general, households in developed countries use more energy than those in transitional or developing nations, primarily as a result of the higher market saturation of energy-using appliances.

Industrialized World

Households in the developed nations of the industrialized world (North America, Western Europe, and Industrialized Asia) have much in common in terms of using energy. Space and water heating account for most of the energy used by households in the industrialized nations, the majority of which are located in the northern latitudes. Although the fuels used to heat both space and water vary from country to country, the recent trend has been toward natural gas and away from oil, coal, and biomass (wood and peat, for example) in most industrialized countries. That trend is expected to continue over the projection period, as natural gas distribution networks are built out in many of the developed nations that do not have complete coverage in terms of a natural gas grid. In some of the Scandinavian countries, where hydropower plays a key role in electricity production and taxes on fossil fuels are high, electricity is more widely used for home heating.

Figure 16. World Installed Nuclear Capacity, 2001-2025



Sources: **2001:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

The technologies used for space and water heating also vary among the industrialized nations. In the United States, for example, central units are widely used to distribute hot water and air through ducts or pipes. Centralized systems tend to use more energy than do systems that heat individual rooms or that heat water inside a dishwasher, shower unit, or other appliance. In the United States, widespread use of air conditioning and the relatively large size of houses have contributed to the prevalence of central heating systems. In Western Europe and Japan, where houses on average are smaller, summer temperatures are more moderate, and energy costs are higher, there has been less reliance on central systems, although they are becoming more commonplace.

Increasingly, other appliances are becoming a bigger part of the energy picture in the developed world. In every industrialized nation, higher incomes have fueled demand for more and more electric appliances, such as home computers, home theater systems, and the like. As appliance standards for products such as refrigerators and clothes washers take hold in the developed nations, growth in electricity consumption is increasingly affected by the penetration of these more efficient appliances—a trend that is expected to continue in the industrialized countries as household incomes rise.

Eastern Europe and the Former Soviet Union

Since the collapse of the Socialist regimes in Eastern Europe, residential energy use, both per household and per capita, has declined in the region's transitional economies. The transition to market economies has had a significant impact on energy use, as energy price subsidies related to government-run energy service providers have waned. Consumers, reacting to higher market prices for energy, have reduced demand accordingly. At the same time, per capita incomes have declined, making energy less affordable.

As in the developed economies, space heating tends to be the most energy-intensive service for households in the transitional economies, where colder climates dictate that a substantial amount of energy be used for heating. In addition, the majority of homes in the EE/FSU countries are relatively energy-inefficient, with relatively high space heating intensities per square foot. The use of coal and wood for space heating tends to be more widespread in the transitional countries than in the developed nations.

The pace of the transition to fully operational market-based economies will determine how patterns of energy use change in the residential sector of the EE/FSU region in the coming decades. As household incomes rise, energy use in the transitional economies is expected to grow with the demand for energy-using appliances. Providing adequate and reliable supplies of electricity to homes will require national investments in electricity production and distribution infrastructure as households begin to use electricity more intensively.

Developing World

Energy use in the developing nations (China, India, Central and South America, Africa, the Middle East, and Other Developing Asia) is projected to increase more rapidly than in other regions over the coming decades. Population growth and urbanization in populous China and India are expected to produce large increases in demand for residential energy services, and rising incomes and rural electrification efforts are generally expected to bolster demand for electricity-using appliances in most of the developing countries. Given the current low market saturation of such appliances, rapid growth in demand for electricity is projected over the forecast period as air conditioning, refrigeration, and laundry equipment become more commonplace. China's electricity supply system already is struggling to meet the demand of its customers, causing brownouts and curtailments. In South America, where air conditioning is more widely used, the electricity infrastructure is better established than in some of the other developing nations.

In most of the developing economies, energy use for space heating tends to be less important than it is in the industrialized nations, due in part to climate and dwelling size. In the poorest nations, available wood, wood waste, and other solid wastes are used for cooking, for water heating, and for space heating where it is needed. Traditional sources of free wood are becoming more scarce, however, as land development and population pressures deplete readily available supplies of forest products. As commercial markets for traditionally free fuels have developed, those who cannot afford the price of wood have turned to burning solid waste for cooking and other uses. Until household incomes in those areas increase, it is likely that the situation will continue as it is. Over time, however, as incomes rise and fuel distribution networks are established, switching to petroleum and natural gas is expected to displace some of the demand for traditional fuels.

Commercial Sector

The commercial sector—often referred to as the services sector or the services and institutional sector—consists of businesses, institutions, and organizations that provide services. The sector encompasses many different types of buildings and a wide range of activities and energy-related services. Examples of commercial sector facilities include schools, stores, correctional institutions, restaurants, hotels, hospitals, museums, office buildings, banks, and even stadiums that hold sporting events. Most commercial energy use occurs in buildings or structures, supplying services such as space heating, water heating, lighting, cooking, and cooling. Energy consumed for services not associated with buildings, such as for traffic lights and city water and sewer services, is also categorized as commercial sector energy use.

Economic and population growth trends drive commercial sector activity and the resulting energy use. The need for services (health, education, financial, government) increases as populations increase. The degree to which these additional needs are met depends in large measure on economic resources—whether from domestic or foreign sources—and economic growth. Economic growth also determines the degree to which additional commercial sector activities are offered and utilized. Higher levels of economic activity and disposable income lead to increased demand for hotels and restaurants to meet business and leisure requirements; for office and retail space to house and service new and expanding businesses; and for cultural and leisure space such as theaters, galleries, and arenas.

Industrialized World

With population growth in the industrialized world as a whole expected to continue slowing, the rate of increase in the region's commercial energy demand is also expected to slow. In addition, further efficiency improvements are also expected to moderate energy demand growth over time as energy-using equipment is replaced with newer, more efficient stock. Conversely, strong economic growth in industrial countries is expected to include continued growth in business activity, with its associated energy use, in areas such as retail and wholesale trade and business, financial, and leisure services.

Electricity demand growth in industrialized countries is becoming more dependent on advances in technology and the introduction of new electronic appliances and equipment. The continued saturation of space cooling in commercial buildings also contributes to increasing electricity use. Recently, natural gas has become the preferred heating fuel in many industrialized nations, displacing petroleum products and coal. In addition to the use of gas-fired systems in buildings, conversion of district heating plants to natural gas (for example, in eastern Germany) has played a role. Growth in commercial natural gas consumption is expected to continue but to slow over time in the industrialized countries; however, some individual countries may continue to see robust growth in commercial natural gas use as it replaces other fuels, such as liquefied petroleum gas (LPG).

Eastern Europe and the Former Soviet Union

Although the population of the EE/FSU region as a whole is projected to decline over the forecast period, increasing commercial activity and rising incomes are expected to lead to growth in the region's commercial sector energy demand. The nations of Eastern Europe are expected to continue a general shift toward services and lighter industries as the transition to market economies continues, with tourism services expected to become increasingly important. As a result, the region's total energy consumption is expected to grow more slowly than its gross domestic product (GDP). Nevertheless, increased demand for commercial services is expected to contribute to continued growth in commercial energy use in absolute terms.

Electricity demand in the EE/FSU region is expected to grow rapidly as the transitional nations approach the requirements of market-based economies, including increased adoption of electronic equipment. Commercial natural gas demand is expected to grow more strongly in the transitional economies than in the industrialized nations as commercial activity increases. Natural gas is also expected to meet the heating needs of transitional countries to a greater extent than it has in the past, displacing coal and heating oil.

Developing World

The commercial sector typically represents a smaller share of energy consumption in developing countries than in industrialized and transitional nations; however, economic growth and commerce are expected to increase rapidly in the developing nations, fueling additional energy demand in the services sector. Faster population growth is also expected in the developing world than in the other regions, increasing the need for education, health care, and social services and the energy required to provide them.

Commercial electricity demand is expected to grow rapidly in developing countries as more clinics, schools, and businesses gain access to electricity. The projected increase in commercial electricity demand is compounded in nations with quickly growing economies, such as China, as they continue to shift away from heavy manufacturing toward services. Increasing commercial activity is expected to lead to growth in natural gas demand as well, with several developing countries focused on expanding the infrastructure necessary for delivery of this relatively clean fuel. Commercial sector oil consumption is expected to continue to increase more rapidly in areas where natural gas availability is limited.

Industrial Sector

Energy is consumed in the industrial sector by a diverse group of industries—including manufacturing, agriculture, mining, and construction—and for a wide range of activities, such as process and assembly uses, space conditioning, and lighting. Overall energy demand in the industrial sector varies across regions and countries of the world, based on the level and mix of economic activity, technological development, and population, among other factors.

Industrialized World

Industrialized countries accounted for one-half of all energy consumption in the industrial sector worldwide in 2001, and the United States accounted for one-half of the total in the industrialized countries. On the other hand, the industrialized countries use much less energy per dollar of GDP than do countries in the EE/FSU and developing regions. Reasons for the differences include more energy-efficient industrial operations and a mix of industrial output more heavily weighted toward non-energy-intensive sectors in the industrialized economies. For example, the United States has seen manufacturing's share of total value of output decline steadily over the past two decades, while that for the service sectors (included in the commercial sector) has increased. Additionally, within the U.S. manufacturing sector, a smaller share of output has been produced by the heavy, energy-intensive industries (such as steelmaking). These general trends are projected to continue. On a per capita basis, delivered energy consumption in the industrial sector is higher in the industrialized countries than in the EE/FSU or developing countries.

Similar developments are expected for the other industrialized nations as increasing international trade fosters a shift toward a less energy-intensive mix of industrial activity. For example, many of Japan's heavy industries are reducing their output as demand for energy-intensive materials increasingly is met by imports from China and other Asian countries. In Germany, a decline in industrial energy intensity in the early 1990s was largely the result of closures of heavy industries in the former East Germany after reunification. Much of Germany's inefficient, energy-intensive eastern capacity has already been shut down, but further improvements are projected as capital stock is replaced and modernized.

Eastern Europe and the Former Soviet Union

In 2001, in the aggregate, the transitional economies of the EE/FSU region had a higher ratio of industrial sector energy consumption to regional GDP than did either the industrialized or developing nations. The relatively high ratio is a result of three factors: the transition to market-based economies has been slow; a higher proportion of total output from the region is from the industrial sector than in the developed countries (the service sectors are less energy intensive than the manufacturing sectors); and much of the industrial sector's production is from inefficient Soviet-era facilities.

Abundant energy resources in the former Soviet Union, along with centralized decisionmaking led to the construction of energy-inefficient industrial capacity. As the transition to market economies progresses, and as inefficient capacity is replaced with modern facilities, the intensity of energy use in the industrial sector is projected to decline more rapidly than in the industrialized countries. Because Russia has the world's largest natural gas reserves, this fuel source is likely to supply one-half of the industrial sector energy requirements in the region.

Developing World

Industrial energy consumption in the developing countries was nearly 40 percent of the worldwide industrial sector total in 2001, and their share is projected to increase to almost one-half of all industrial sector energy consumption by 2025 as a result of the more rapid economic growth expected in the region. The ratio of industrial sector energy consumption to GDP is projected to decline at approximately the same rate as in the industrialized countries.

China leads the developing countries in terms of both economic growth and industrial energy consumption. Two energy-intensive industries, iron and steel and chemicals, are projected to increase capacity, both to meet domestic needs and to supply international markets. As the standard of living in China rises, however, less energy-intensive light industries are projected to increase output even faster, in order to meet growing demand for consumer products.

Outlook for Carbon Dioxide Emissions

World carbon dioxide emissions are expected to increase from 23,899 million metric tons[5] in 2001 to 37,124 million metric tons in 2025—growing by 1.9 percent per year—if world energy consumption reaches the levels projected in the *IEO2004* reference case (Figure 17). According to this projection, world carbon dioxide emissions in 2025 would exceed 1990 levels by 72 percent. Combustion of petroleum products contributes 5,733 million metric tons to the projected increase from 2001, coal 4,120 million metric tons, and natural gas the remaining 3,374 million metric tons. Although coal use is projected to grow at a slower rate than natural gas use over the projection period, coal is also a more carbon-intensive fuel than gas. As a result, the absolute increment in carbon dioxide emissions from coal combustion is larger than the increment in emissions from natural gas combustion.

Carbon dioxide emissions from energy use in the industrialized countries are expected to increase by 4,009 million metric tons, to 15,643 million metric tons in 2025, or by about 1.2 percent per year. Emissions from the combustion of petroleum products account for about 42 percent of the total increment expected for the industrialized world, natural gas 33 percent, and coal 24 percent.

[5] In keeping with current international practice, *IEO2004* presents data on carbon dioxide emissions in million metric tons carbon dioxide equivalent. The figures can be converted to carbon equivalent units by multiplying by 12/44.

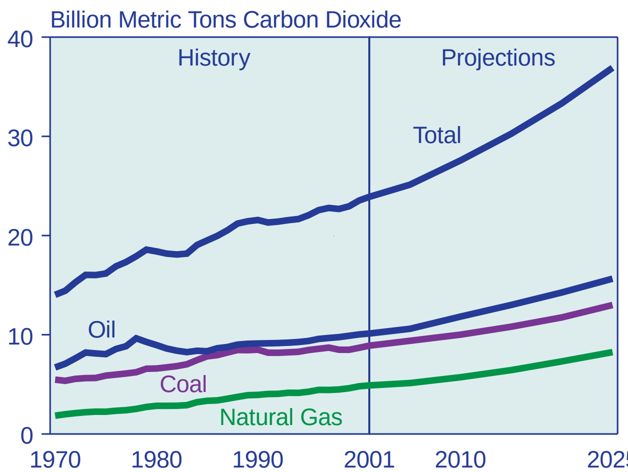
By 2020, carbon dioxide emissions in the developing world (including China and India) are expected to surpass those in the industrialized countries, even though developing countries are projected to use less total energy than industrialized countries at that time (Figure 18). However, developing countries continue to account for less than one-half of global carbon dioxide emissions through the 2025 forecast horizon. Total emissions in developing nations are expected to increase from 9,118 million metric tons in 2001 to a total of 17,168 million metric tons in 2025, representing about 61 percent of the projected increase worldwide. The sizable rise in emissions projected for the developing nations results in part from their continued heavy reliance on coal, the most carbon-intensive of the fossil fuels. Coal is used extensively in the countries of developing Asia, which have the highest expected rates of economic growth and energy consumption growth in the forecast. Carbon dioxide emissions in developing Asia alone are projected to increase from 6,012 million metric tons in 2001 to 11,801 million metric tons in 2025.

In the EE/FSU region, carbon dioxide emissions are not expected to return to their Soviet-era levels during the projection period. The *IEO2004* reference case projection reflects the expectation that coal use will not decline as precipitously as was projected in last year's *IEO*, particularly among the FSU countries. In fact, Russia's coal use is expected to increase slowly until 2015 before it begins to decline. The FSU appears to be in the midst of sustained economic recovery after the political, social, and economic upheavals that followed the breakup of the Soviet Union in the early 1990s. Carbon dioxide emissions are not expected to increase as quickly as energy use because of gains in energy efficiency resulting from the replacement of old, inefficient capital stock, and because in many countries in the region, natural gas is expected to displace coal, particularly for new electricity generation capacity.

Worldwide, carbon dioxide emissions per person are projected to increase from about 4.1 metric tons in 1990 to 4.7 metric tons in 2025. Per capita emissions in the industrialized countries remain much higher than those in the rest of the world throughout the projection period, increasing from 11.8 to 12.9 metric tons per person between 1990 and 2010 and then to 14.7 metric tons per person in 2025 in the *IEO2004* reference case (Figure 19).

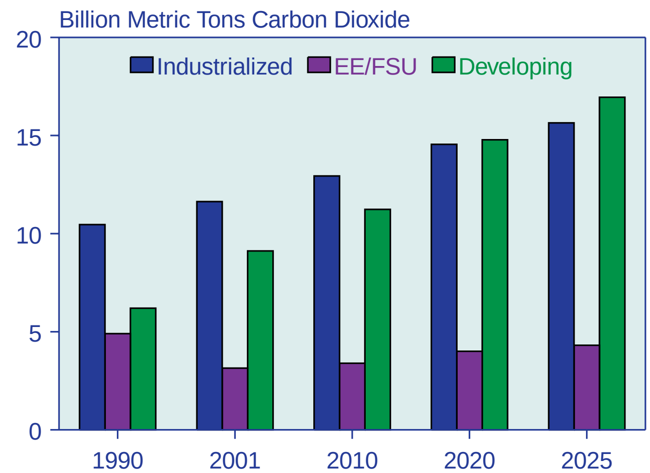
As of November 26, 2003, 119 countries and the European Community had ratified the Kyoto Protocol. Thirty-one of the ratifying nations are the so-called Annex I countries, which are required to limit or reduce their greenhouse gases relative to 1990 levels under the terms of the Protocol.[6] The Kyoto Protocol will enter into force 90 days after it has been ratified by at least 55 of the parties to the United Nations Framework Convention on Climate Change (UNFCCC), including a representation

Figure 17. World Energy-Related Carbon Dioxide Emissions by Fuel Type, 1970-2025



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

Figure 18. World Energy-Related Carbon Dioxide Emissions by Region, 1990-2025



Sources: **1990 and 2001:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219 (2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

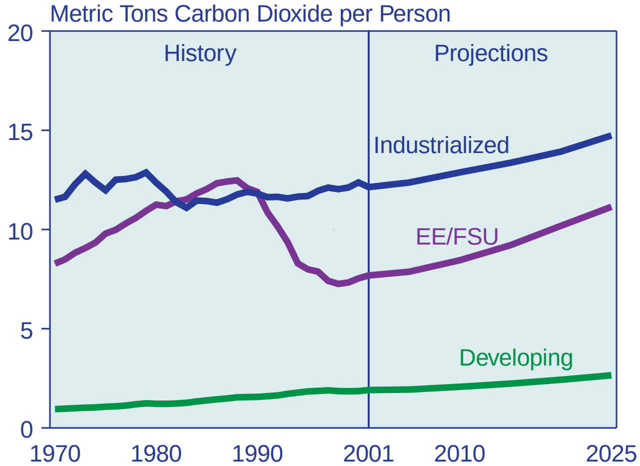
[6] As of November 26, 2003, the following Annex I countries had ratified, accepted, approved, or acceded to the Kyoto Protocol: Austria, Belgium, Bulgaria, Canada, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Lithuania, Luxembourg, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, and the United Kingdom.

of Annex I countries accounting for at least 55 percent of the total 1990 carbon dioxide emissions from the Annex I group. Countries that already have ratified the Protocol include Annex I countries responsible for about 44 percent of total Annex I carbon dioxide emissions in 1990.

Because Russia accounted for 17 percent of the 1990 Annex I carbon dioxide emissions, its ratification would bring the Protocol into force for its signatories if Russia met the Protocol's requirements for verifying and monitoring emissions levels. Conflicting statements concerning the prospects for Russia's ratification of the Kyoto Protocol have recently been released. In December 2003, Andrei Illarionov, a senior adviser to President Vladimir Putin, said that the country was not planning to ratify the treaty. Two days later, the Russian deputy economic minister, Mukhamed Tsikhanov said, "There are no decisions about ratification apart from the fact that we are moving towards ratification" [**2**]. Most Russia watchers agree that no action will be taken with regard to the treaty until well after the national elections scheduled for March 2004 [***3***].

Both China and India ratified the Kyoto Protocol in 2002. Although both countries account for significant amounts of the world's carbon dioxide emissions, their ratification does not affect the implementation of the Protocol, because neither country is an Annex I member. In 2001, China and India together accounted for 17 percent of total world carbon dioxide emissions, as compared with the 24-percent share made up by U.S. emissions in that year.

Figure 19. Energy-Related Carbon Dioxide Emissions per Capita by Region, 1970-2025



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

In the United States, the Bush Administration has stated that it will not seek to ratify the Kyoto Protocol. Its policy om limiting greenhouse gas emissions focuses on initiatives aimed at reducing greenhouse gas intensity as an alternative to the Protocol.[7] Under the President's Clear Skies Initiative[8] and Global Climate Change Initiative, the United States will work to reduce greenhouse gas intensity by 18 percent from 2002 levels by 2012 [***4***]. Carbon dioxide intensity is defined as the amount of carbon dioxide emitted per dollar of GDP. This measurement illustrates the relationship between emissions and the expansion of economic activity. The Administration argues that reducing the amount of greenhouse gases emitted per dollar of GDP will slow the rate of increase in emissions without sacrificing needed economic growth.

World carbon dioxide intensity has improved (decreased) substantially over the past three decades, from 1,100 metric tons per million 1997 dollars of GDP in 1970 to 739 metric tons per million 1997 dollars in 2001 (Table 2). Although the pace of improvement in emissions intensity is expected to slow over the forecast period, it still continues to improve in the reference case projections, dropping to 566 metric tons per million 1997 dollars in 2025, about 24 percent less than in 2001.

On a regional basis, the most rapid improvements in carbon dioxide intensity are expected to occur among the transitional economies of the EE/FSU and in China. Russia's carbon dioxide intensity improves by 2.5 percent per year in the forecast, as the country continues to recover from the economic upheaval of the 1990s and replaces old and inefficient capital stock as economic recovery progresses. Outside Russia, carbon dioxide intensity in the rest of the FSU region falls even more rapidly, by 3.2 percent per year between 2001 and 2025, with economic recovery expected to continue throughout the forecast.

In addition to improved efficiency of capital equipment, the FSU nations are also expected to increase their use of less carbon-intensive natural gas for new electricity generation and other end uses rather than the more carbon-intensive oil and coal. There are expansive natural gas resources in Russia, but there are also significant gas resources in several other key economies of the FSU, including Turkmenistan, Uzbekistan, and Kazakhstan, as well as to a lesser extent in Azerbaijan and Ukraine.

[7]Greenhouse gases are transparent to solar (short-wave) radiation but opaque to long-wave (infrared) radiation and thus prevent long-wave radiant energy from leaving the Earth's atmosphere. The most important greenhouse gases are water vapor, carbon dioxide, methane, nitrous oxide, and several engineered gases, including hydrofluorocarbons, perfluorocoarbons, and sulfur hexafluoride.

[8]The Clear Skies Initiative proposes a voluntary program that would use a "cap and trade" system, allowing companies to trade emissions credits in an effort to achieve significant reductions in emissions of mercury, nitrogen oxides, and sulfur dioxide.

Those resources have only just begun to be developed and have not been as widely utilized as the resources in Russia. Development of natural gas reserves over the forecast period is expected to allow the other nations of the FSU region to achieve more rapid improvements in carbon dioxide intensity than is projected for Russia.

Eastern Europe began its economic recovery much earlier than the nations of the former Soviet Union. As a result of strong investment in improving the efficiency of energy use among Eastern European countries and a push to increase the use of natural gas, carbon dioxide intensity fell by nearly 40 percent in Eastern Europe between 1990 and 2001, as compared with only 5 percent in Russia and 9 percent in the other FSU nations. Improvement in carbon dioxide intensity in Eastern Europe is projected to continue outpacing that in Russia, at 2.9 percent per year from 2001 to 2025.

Developing Asia is expected to see fairly rapid improvement in carbon dioxide intensity over the projection period, primarily as a result of rapid economic growth, rather than a switch to less carbon-intensive fuels. China, in particular, is expected to remain heavily reliant on fossil fuels, especially coal, in the *IEO2004* reference case, but its annual GDP growth is projected to average 6.1 percent, compared with an expected 3.3-percent annual rate of increase in fossil fuel use from 2001 to 2025. China's carbon dioxide intensity is expected to decrease by 2.6 percent per year over the forecast period.

Table 2. World Carbon Dioxide Intensity by Selected Countries and Regions, 1970-2025
(Metric Tons Carbon Dioxide per Million 1997 U.S. Dollars of Gross Domestic Product)

Region	History				Projections				Average Annual Percent Change	
	1970	1980	1990	2001	2010	2015	2020	2025	1970-2001	2001-2025
Industrialized Countries										
North America										
United States	1,154	946	729	606	528	489	457	431	-2.1	-1.4
Canada	1,272	1,090	855	757	699	655	611	581	-1.7	-1.1
Mexico	673	827	929	760	714	674	625	596	0.4	-1.0
Western Europe										
United Kingdom	813	696	521	377	329	307	282	261	-2.4	-1.5
France	535	484	288	248	207	189	170	157	-2.5	-1.9
Germany	855	711	519	358	330	311	309	292	-2.8	-0.8
Italy	487	439	391	351	330	311	292	274	-1.0	-1.0
Netherlands	780	773	666	579	537	501	463	425	-1.0	-1.3
Industrialized Asia										
Japan	457	386	259	263	244	229	215	207	-1.8	-1.0
Australia/New Zealand	1,190	795	770	733	636	598	564	551	-1.5	-1.2
EE/FSU										
Russia	2,804	3,120	3,603	3,425	2,579	2,277	2,061	1,877	0.6	-2.5
Other Former Soviet Union	4,537	4,763	5,334	4,873	2,932	2,610	2,385	2,215	0.2	-3.2
Eastern Europe	3,558	3,698	3,124	1,923	1,449	1,239	1,096	947	-2.0	-2.9
Developing Countries										
Asia										
China	9,703	8,218	5,288	2,538	1,824	1,619	1,468	1,340	-4.2	-2.6
India	1,719	1,965	1,933	1,764	1,369	1,244	1,140	1,044	0.1	-2.2
South Korea	936	1,033	783	789	620	555	505	477	-0.6	-2.1
Middle East	1,391	1,565	2,069	2,225	1,908	1,752	1,624	1,519	1.5	-1.6
Africa	1,108	1,199	1,345	1,348	1,076	1,008	945	885	0.6	-1.7
Central and South America	686	611	637	638	607	561	532	505	-0.2	-1.0
Total World	**1,100**	**1,008**	**877**	**739**	**658**	**621**	**591**	**566**	**-1.3**	**-1.1**

Sources: **History:** Derived from Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219 (2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

World Economic Outlook

Economic growth is among the most important factors to be considered in projecting changes in the world's energy consumption over time. In the *IEO2004* forecast, assumptions about regional economic growth, measured in gross domestic product (GDP) in real 1997 U.S. dollars, underlie the projections of regional energy demand (see box below for discussion of real GDP). The *IEO2004* reference case projection for economic growth is based on projections provided in the Energy Information Administration's *Annual Energy Outlook 2004* for the United States and by Global Insight, Inc., for all other countries [**5**]. The framework employed for the projections reflects the interaction of many economic variables and underlying relationships, both in the short term and in the medium to long term. In the short term, households and businesses make spending decisions (the demand side) based on their expectations of future movements in interest rates, prices, employment, incomes, wealth, fiscal and monetary policies, exchange rates, and world developments. In the long run, it is the ability to produce goods and services (the supply side) that ultimately determines the growth potential for any country's economy.

While the short-term movements of actual output of a nation move around a trend, depending upon which stage of the business cycle the economy is in, the medium- to long-term forecast has to do with projecting the trend in output itself. The *IEO2004* reference case economic forecast is a projection of possible economic

Converting Gross Domestic Product for Different Countries to U.S. Dollars: Market Exchange Rates and Purchasing Power Parity Rates

The world energy forecasts in *IEO2004* are based primarily on projections of GDP for different countries and regions, which for purposes of comparison are expressed in 1997 U.S. dollars. First, GDP projections are prepared for the individual countries in terms of their own national currencies and 1997 prices of goods and services. Then, the projections are converted to 1997 U.S. dollars by applying average 1997 foreign exchange rates between the various national currencies and the dollar. The resulting projections of real GDP are thus based on national 1997 prices in each country and the 1997 market exchange rate (MER) for each currency against the U.S. dollar.

An alternative method for converting GDP projections in different national currencies to U.S. dollars would employ exchange rates based not on currency markets but on the concept of "purchasing power parity" (PPP). PPP exchange rates are derived through a process of equalizing the purchasing power of different currencies by eliminating differences in price levels for various goods. As one example, if the price of a hamburger is $2.20 in the United States and 60 rupees in India, then the PPP exchange rate for hamburgers between the two currencies can be calculated as 60/2.2, or 27.3 rupees to the dollar.[a] Similarly, the concept of PPP for one good can be generalized to various baskets of goods and services in different countries to derive PPP rates for converting aggregate national income and product accounts to U.S. dollars.[b]

The table on the following page shows 2001 GDP and the *IEO2004* projections for 2025 GDP, converted to 1997 U.S. dollars based on 1997 MER and PPP rates for various countries and regions, as well as the ratios of the two results. For most of the industrialized countries, the ratio of 2001 GDP based on MER to that based on PPP is close to 1, indicating that the cost of living in those countries generally is reflected in the exchange rates for their currencies. Two exceptions are Mexico and Japan. For Mexico the ratio is 2.3, implying a much lower cost of living than in the United States and thus an economy that is 2.3 times larger than suggested by the MER-based real GDP calculation. For Japan the ratio is 0.7, implying a higher cost of living than in the United States and, in terms of purchasing power, an economy that is 30 percent smaller than suggested by the MER-based GDP. The ratios for the developing countries are much larger—including values of 5.1 for China and 5.6 for India.

In terms of the *IEO2004* forecasts, however, the apparent discrepancy between the MER and PPP conversion results for 2001 GDP does not mean that the two methods would yield different energy demand projections. Comparison of the PPP/MER ratios for historical 2001 GDP and projected 2025 GDP shows that, for each country and region, the two ratios are identical. In other words, it makes no difference for the energy demand forecasts whether the GDP forecasts are based on MER or PPP as long as they are consistent over the entire period, because both forecasts are based on volumes, which do not reflect changes in exchange rates and prices over time.

(continued on page 18)

[a]See "McCurrencies," *The Economist* (April 24, 2003).
[b]The main sources of information on purchasing power parity are the International Comparison Program (ICP) of the United Nations, web site http://pwt.econ.upenn.edu, and the Joint OECD-Eurostat PPP Programme, web site www.oecd.org.

growth, from the short term to the long term, in a consistent framework that stresses demand factors in the short term and supply factors in the long term. Currently, based on historical trends, the world economy is operating below its potential. Given the recent positive economic news coming from the United States, Japan, Western Europe, China, and Russia, the expectation is that the world economy will continue moving toward its long-term growth potential in 2004 and 2005.

Beyond 2005, the outlook for medium- to long-term economic growth depends on the underlying demographic and expected productivity trends in each economy. These in turn depend on population growth, labor force participation rates, productivity growth, and national savings and capital accumulation. These factors determine the nature and character of long-term growth, especially in developed industrial economies that have well-established and stable political institutions and markets for goods and services, labor, and financial assets. These economies generally have well-defined property rights and well-developed human and physical infrastructures.

In developing economies that are still in the process of building their human and physical capital infrastructures, establishing regulatory mechanisms to govern markets, and ensuring political stability will play an important role in determining medium- to long-term growth potential. The transitional economies face their own unique sets of problems as they move from central planning to decentralized private markets. Therefore, in contrast to the developed world, the range of uncertainty about the reference case projections for developing and transitional economies is higher.

Industrialized World

The U.S. economy has started to improve vigorously after a number of serious setbacks in the past three years, including the terrorist attacks of September 2001, the significant loss of stock market wealth since 2000, corporate accounting scandals, the war on terrorism, and the wars

Comparison of Real GDP by Region and Country for 2001 and 2025 Converted to 1997 U.S. Dollars Based on Purchasing Power Parity Rates (PPP) and Market Exchange Rates (MER)

Region	2001 Real GDP			Projected Real GDP, 2025		
	PPP	MER	PPP/MER	PPP	MER	PPP/MER
Industrialized Countries	**23,542**	**25,077**	**0.9**	**41,848**	**44,545**	**0.9**
United States	9,394	9,394	1.0	18,881	18,881	1.0
Canada	823	751	1.1	1,570	1,427	1.1
Mexico	1,062	464	2.3	2,640	1,153	2.3
Western Europe	8,624	9,513	0.9	13,993	15,423	0.9
United Kingdom	1,399	1,492	0.9	2,494	2,655	0.9
France	1,448	1,601	0.9	2,384	2,629	0.9
Germany	1,842	2,284	0.8	2,679	3,313	0.8
Italy	1,307	1,269	1.0	2,028	1,971	1.0
Japan	3,087	4,411	0.7	4,592	6,563	0.7
Australia/New Zealand	734	428	1.7	1,155	674	1.7
EE/FSU	**2,137**	**1,022**	**2.1**	**5,593**	**2,680**	**2.1**
Former Soviet Union	1,376	632	2.2	3,709	1,710	2.2
Eastern Europe	762	389	2.0	1,899	971	2.0
Developing Asia	**12,391**	**3,536**	**3.5**	**41,051**	**11,714**	**3.5**
China	6,074	1,202	5.1	25,155	4,976	5.1
India	2,902	520	5.6	9,808	1,757	5.6
South Korea	822	562	1.5	2,209	1,510	1.5
Other Asia	2,756	1,253	2.2	7,569	3,471	2.2
Middle East	**1,100**	**584**	**1.9**	**2,608**	**1,389**	**1.9**
Turkey	410	183	2.2	1,101	492	2.2
Central & South America	**1,980**	**1,510**	**1.3**	**4,763**	**3,650**	**1.3**
Brazil	986	863	1.1	2,372	2,076	1.1

Sources: Energy Information Administration, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004); Global Insight, Inc., *World Overview* (Lexington, MA, September 2003); and International Monetary Fund, "How Should We Measure Global Growth?", in *World Economic Outlook: Public Debt in Emerging Markets* (September 2003), pp. 18-19.

in Afghanistan and Iraq. Yet the recession of 2001 was one of the mildest on record, with recovery proceeding slowly in 2002 and 2003. The mildness of the recession was the result of a collapse in business investment, which was largely offset by sustained private spending on consumption, a strong housing market, and expansionary fiscal and monetary policies. In the mid-term, the U.S. economy is projected to grow by an average of 3.2 percent per year between 2005 and 2010, with somewhat slower growth—2.8 percent per year—expected between 2010 and 2025 (Table 3 and Figure 20).

In Canada, economic growth was more robust than that in the United States from 1998 through 2002; however, in conjunction with the general worldwide economic slowdown, it slowed substantially during the first half of 2003. The slowdown in the United States (one of Canada's major trading partners), the appreciation of the Canadian dollar, and some SARS-related problems contributed to the Canadian slowdown [*6*]. As the recovery proceeds in the United States, the Canadian economy is expected to rebound, and average economic growth rates of 3.0 percent per year between 2005 and 2010 and 2.5 percent per year between 2010 and 2025 are projected in the *IEO2004* reference case.

Growth in Mexico's economy was disappointing during the first half of 2003, reflecting in part the sluggishness of the U.S. economy. Mexico's estimated economic growth rate for the year is 1.5 percent. Unlike the Canadian dollar, there has been no sharp appreciation of the Mexican peso against the U.S. currency. Output remains well below potential. Global financial markets remain friendly to Mexico in terms of the availability and cost of credit and the volume of foreign direct investment. In general, strong trade ties with the United States are expected to help cushion Mexico from the deeper economic troubles that have hampered other countries in

Table 3. Annual Growth in World Gross Domestic Product by Selected Countries and Regions, 1977-2025
(Percent per Year)

Region	History				Projections		
	1977-2001	2001	2002	2003	2001-2025	2005-2010	2010-2025
Industrialized Countries	**2.7**	**0.9**	**1.5**	**1.7**	**2.4**	**2.6**	**2.4**
United States	3.0	0.3	2.4	2.3	3.0	3.2	2.8
Canada	2.9	1.9	3.3	2.0	2.7	3.0	2.5
Mexico	3.3	-0.3	0.9	1.5	3.9	3.6	4.4
Western Europe	2.2	1.7	1.0	0.7	2.0	2.2	2.1
United Kingdom	2.3	2.1	1.7	2.0	2.4	2.5	2.5
France	2.2	2.1	1.2	0.3	2.1	2.2	2.2
Germany	1.9	1.0	0.2	0.0	1.6	1.8	1.7
Italy	2.2	1.7	0.4	0.3	1.9	2.1	2.0
Japan	2.9	0.4	0.2	2.5	1.7	1.8	1.7
Australia/New Zealand	3.1	2.5	3.7	2.6	3.0	3.0	2.9
EE/FSU	**-0.4**	**4.6**	**4.0**	**5.1**	**4.1**	**4.4**	**3.9**
Former Soviet Union	-1.0	5.9	4.8	6.1	4.2	4.5	3.8
Eastern Europe	0.8	2.6	2.7	3.4	3.9	4.1	3.9
Developing Countries	**4.5**	**2.4**	**3.5**	**3.9**	**4.6**	**5.2**	**4.5**
Asia	6.8	3.9	5.6	5.2	5.1	5.8	4.7
China	9.5	7.3	8.0	7.7	6.1	6.8	5.5
India	5.2	5.6	4.3	5.8	5.2	5.4	5.1
South Korea	6.9	3.2	6.3	2.8	4.2	5.6	3.4
Other Asia	5.8	0.5	3.6	3.5	4.3	5.1	4.2
Middle East	3.3	-1.7	3.3	3.9	3.7	4.0	3.6
Turkey	3.3	-7.5	7.8	5.0	4.2	4.2	3.9
Africa	2.7	3.2	3.0	3.3	4.0	4.5	3.9
Central and South America	2.4	0.5	-1.2	1.1	3.7	4.1	4.2
Brazil	2.7	1.4	1.5	0.5	3.7	3.9	4.1
Total World	**2.8**	**1.3**	**2.0**	**2.3**	**3.0**	**3.2**	**3.0**

Sources: **History:** Global Insight, Inc., *World Overview* (Lexington, MA, September 2003). **Projections:** Global Insight, Inc., *World Overview* (Lexington, MA, September 2003); and Energy Information Administration, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004).

Latin America. By the same token, Mexico's future growth is also more dependent on U.S. growth. In the *IEO2004* reference case, Mexico's GDP is projected to grow by an average of 3.9 percent per year from 2001 to 2025.

Economic performance in Western Europe, particularly the Eurozone, has also been disappointing. Real GDP growth (and growth of real domestic demand) has been sluggish for the past 3 years, and fiscal and monetary policy actions to induce more satisfactory growth have not been exercised [***7***]. The region's actual GDP is well below potential, and even with some economic acceleration there is little reason to expect that the gap between actual and potential output will shrink significantly any time soon. Moreover, some analysts believe that macroeconomic policy (particularly, monetary policy) in the Eurozone has not been aggressive enough in confronting the widening output gap. In the face of accumulating evidence of underlying economic sluggishness, the European Central Bank has cut key interest rates far less and much more slowly than has the U.S. Federal Reserve [***8***].

Over the medium to long term there are structural impediments to economic growth in many European countries—particularly relating to labor markets, product markets, and costly social welfare systems. Reforms to improve the competitiveness of European labor and product markets could yield significant dividends in terms of increases in regional output. Several countries have recently introduced or at least proposed substantive reforms, including further liberalization of labor and product markets in Germany and pension reforms in France, Italy, and Austria [***9***]. In the *IEO2004* reference case, Western Europe's GDP is projected to grow by 2.0 percent per year between 2001 and 2025—a full percentage point lower than the average annual growth rate projected for U.S. GDP over the same period.

Japan, the world's second largest economy, grew by only 0.2 percent in 2002, with strong exports being the major factor preventing the economy from falling into recession [***10***]. Although not robust, Japan's positive growth performance during the first and second quarters of 2003 surprised most analysts [***11***]. Japan's future long-term growth still has great potential. The country's highly skilled labor force and strong work ethic should allow high rates of growth, provided that more flexible labor policies are adopted, allowing greater mobility for workers. Toward the end of the decade, normal attrition is expected to eliminate excessive employment in the industrial sector, allowing consolidation and improved efficiencies. More importantly, the bankrupt firms kept afloat by creditors are expected to be gone and, therefore, no longer a drain on the economy. In addition, the bad loans that have plagued Japan's banks are expected to be reduced to the point where lending can again take place.

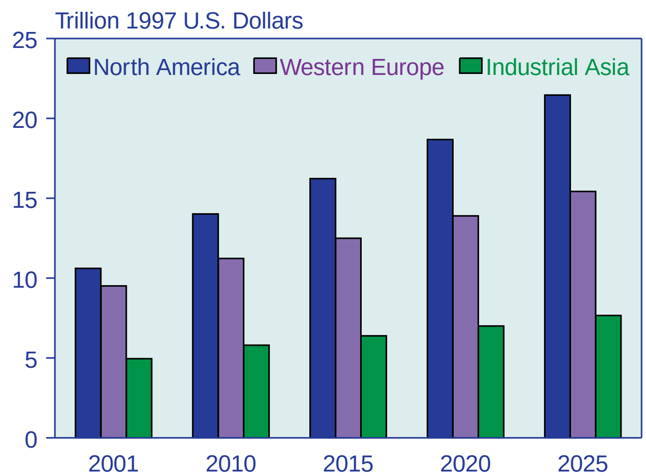
On the potentially negative side is Japan's declining population. The number of people is expected to peak in 2007, and the average age is expected to continue rising as a result of a low birth rate and high longevity. This implies that transfer payments by the government to the elderly could become increasingly burdensome. Because of the demographic trends, Japan's projected average annual GDP growth rate of 1.7 percent from 2001 to 2025 is less than its projected average per-capita GDP growth rate of 2 percent per year. For the same reasons, Japan's high savings rate is expected to decline. With less need to invest overseas, capital outflows from Japan should fall, which would allow the yen to strengthen, reducing the country's trade surplus [***12***].

Eastern Europe and the Former Soviet Union

For the past several years, the economies of the FSU continue to be largely sheltered from global economic uncertainties, having recorded strong growth each year since 2000. Robust domestic demand in both Russia and Ukraine, in addition to rising oil prices and corresponding hydrocarbon investment in the Caspian region, has been the primary cause of the expansion. In Central Asia, many economies continue to surge as a result of large oil and gas investments, while smaller economies are benefiting from expansion in their mining and metals sectors [***13***].

Economic growth in the FSU region is expected to slow from 6.1 percent in 2003 to 5.3 percent in 2004 and 4.9 percent in 2005, based on the assumption of a decline in

Figure 20. Industrialized World Gross Domestic Product by Region, 2001-2025



Sources: **2001:** Derived from Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

oil prices in both 2004 and 2005 and a corresponding decline in the growth impetus produced by higher state spending. Although structural reforms are being pursued in many FSU countries, in general, implementation is not as advanced or as widespread as in the Eastern European economies, and in some cases there is significant resistance to structural reforms. This implies lower long-run growth in comparison.

The recent boom in hydrocarbon prices has provided an important impetus to growth, facilitating the introduction of a number of reforms in oil-exporting economies and contributing to an increase in investment outlays, particularly in the energy sector. However, given the volatility of energy market prices, these economies will not be able to sustain the growth rates recently achieved until diversification from energy becomes more broadly based. Given the degree of energy dependence in many of the FSU countries, particularly Russia, the projected softening of oil prices in the *IEO2004* reference case forecast implies a slowing down of the region's growth from recent high rates.

Most Eastern European countries had positive GDP growth by the mid-1990s, following the declines associated with the dissolution of the Soviet Union. Catastrophic floods in August 2002 had strong negative impacts on the important regional economy of the Czech Republic. Also, the slowdown among the economies of the industrialized world dampened some demand for East European goods. Therefore, economic growth in the Eastern European economies has been flat for the past year.

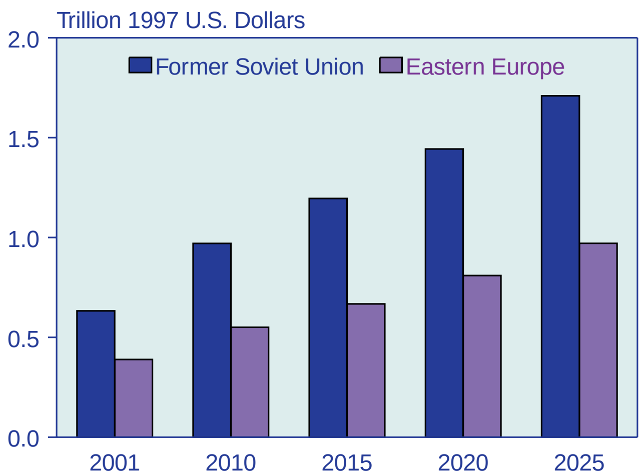
The accession of 10 Eastern European countries to membership in the European Union in May 2004 is expected to provide a boost to confidence and to economic activity in the mid-term; and an average annual expansion of 3.9 percent per year is projected for Eastern Europe's GDP over the 2001-2025 period (Figure 21). Although participation in the Eurozone will be neither immediate nor automatic, membership in the European Union is expected to provide stimulus to inward foreign direct investment flows—thereby boosting domestic investment and growth. Stronger economic growth in Western Europe will also provide a short-term boost.

Developing World

Much of the growth in world economic activity between 2001 and 2025 is expected to occur among the nations of developing Asia, where regional GDP is projected to grow by 5.1 percent per year (Figure 22). For the most part, the nations of developing Asia experienced positive and accelerating economic growth in 2002. Real GDP in the region grew by 5.6 percent in 2002, as compared with 3.9 percent in 2001. However, the renewed economic slowdown in the developed world, relatively high oil prices in the first part of 2003, and the SARS outbreak in East Asia dampened the pace of regional growth in the first half of 2003.

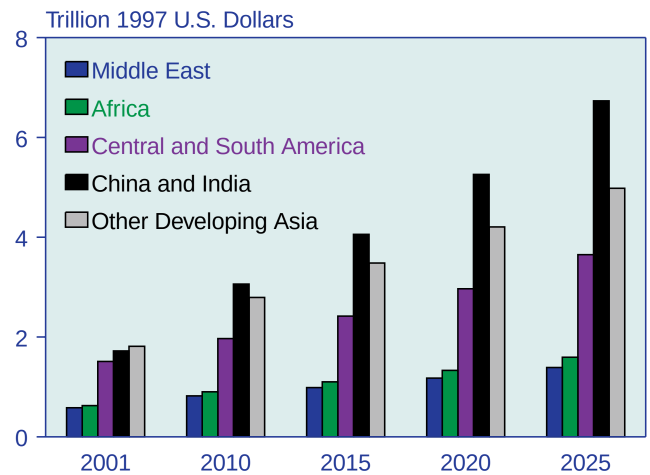
IEO2004 projects an average annual growth rate of approximately 6 percent over the 2001 to 2025 period for China, developing Asia's largest economy. Economic growth in China is expected to be the highest among the world's major economies and by 2025, based on share of world GDP, China is expected to be the third largest economy in the world, behind the United States and Japan (Table 4). In terms of structural issues that have implications for the medium to long term, China still needs to reform overstaffed and inefficient state-owned

Figure 21. EE/FSU Gross Domestic Product by Region, 2001-2025



Sources: **2001:** Derived from Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

Figure 22. Developing World Gross Domestic Product by Region, 2001-2025



Sources: **2001:** Derived from Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

companies and a banking system that is carrying a significant amount of nonperforming loans. Membership in the World Trade Organization is expected to force the government to pursue the reforms, which are expected to transform the Chinese economy into one that is more market oriented and, hence, more efficient. Another major structural factor for China is its present political system. Unlike most European ex-Communist countries, China has done nothing structural to reform its political system.

Structural problems aside, China possesses some very favorable factors for long-term growth. The country has a very high saving rate, at around 40 percent, which allows for faster capital accumulation. It has an abundance of natural resources and a huge, underutilized labor force of both low-skilled and highly skilled workers. Finally, China also is a magnet for attracting capital from abroad. Inflows of foreign capital have averaged $40 billion per year in the past several years [***14***]. In addition to complementing local savings, foreign investment facilitates technology transfer and boosts productivity.

Economic growth in another rapidly emerging economy of the region, India, slowed in late 2002 and early 2003, mainly reflecting the effects of a severe drought on the country's large agricultural sector. Annual GDP growth in 2002 was 4.3 percent, in contrast to 5.6 percent in 2001. Economic activity appears to have picked up significantly in the second quarter of 2003, with recovery in the country's agricultural sector. In addition, falling agricultural prices are helping to provide room for the Reserve Bank of India to ease interest rates, which will be a positive factor for investment and economic growth. Aside from a recovery in agricultural output, growth in India is likely to be supported by continued strong expansion

Table 4. Shares of World Gross Domestic Product by Selected Countries and Regions, 2000-2025
(Percent)

Region	2000	Projections				
		2005	2010	2015	2020	2025
Industrialized Countries	**77.8**	**75.9**	**73.7**	**71.6**	**69.7**	**67.9**
United States	29.3	29.5	29.5	29.3	29.1	28.8
Canada	2.3	2.4	2.3	2.3	2.2	2.2
Mexico	1.5	1.4	1.4	1.5	1.6	1.8
Western Europe	29.3	28.0	26.7	25.5	24.5	23.5
United Kingdom	4.6	4.5	4.4	4.3	4.2	4.0
France	4.9	4.7	4.5	4.3	4.1	4.0
Germany	7.1	6.6	6.1	5.7	5.4	5.1
Italy	3.9	3.7	3.5	3.3	3.2	3.0
Japan	13.8	12.9	12.1	11.3	10.7	10.0
Australia/New Zealand	1.7	1.7	1.7	1.7	1.7	1.7
EE/FSU	**3.1**	**3.4**	**3.6**	**3.8**	**4.0**	**4.1**
Former Soviet Union	1.9	2.2	2.3	2.4	2.5	2.6
Eastern Europe	1.2	1.2	1.3	1.4	1.4	1.5
Developing Countries	**19.1**	**20.6**	**22.7**	**24.6**	**26.3**	**28.0**
Asia	10.7	12.3	13.9	15.4	16.7	17.9
China	3.5	4.5	5.3	6.1	6.8	7.6
India	1.5	1.8	2.0	2.2	2.4	2.7
South Korea	1.7	1.9	2.2	2.3	2.3	2.3
Other Asia	3.9	4.1	4.5	4.8	5.1	5.3
Middle East	1.9	1.9	1.9	2.0	2.1	2.1
Turkey	0.6	0.6	0.7	0.7	0.7	0.8
Africa	1.9	2.0	2.1	2.2	2.3	2.4
Central and South America	4.7	4.5	4.7	4.9	5.2	5.6
Brazil	2.7	2.6	2.7	2.8	3.0	3.2

Sources: **2000:** Global Insight, Inc., *World Overview* (Lexington, MA, September 2003). **Projections:** Global Insight, Inc., *World Overview* (Lexington, MA, September 2003); and Energy Information Administration, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004).

in the information technology services sectors now burgeoning in the Bangalore area [*15*].

The mid-term prospects for India are positive as it continues to privatize state enterprises and increasingly adopts free market policies. It is expected that India will continue structural reforms, including reforms in trade, banking, privatization, and infrastructure. These factors—combined with improvement in human capital indicators in recent years, such as rising literacy rates and school enrollments and declining infant mortality rates—are expected to lead to an increase in productivity [*16*]. Accelerating structural reforms—including ending regulatory impediments to consolidation in labor-intensive industries, labor markets, and bankruptcy reforms, as well as agricultural and trade liberalization—remain essential to stimulate potential growth and to reduce poverty in the medium to long term [*17*]. In the long term, through its vast and cheap labor force, India is well placed to reap the benefits of globalization [*18*]. Average annual GDP growth in India over the 2001-2025 forecast period is projected at 5.2 percent.

After contracting by 1.2 percent in 2002, the aggregate economy of Central and South America (Figure 22) is making a limited recovery. This reflects tentative recoveries in Argentina and Uruguay as well as calming of pre-election jitters in Brazil at the end of 2002. Growth in 2003 is estimated at 1.1 percent. Although the region is on a favorable recovery path, its growth rate remains well below potential. The weak international environment and domestic economic and/or political problems in a number of countries are constraints. Growth in the region remains heavily dependent on the volume of foreign capital flows. Although foreign direct investment continues to be the major source of external finance, inflows are generally weak, while portfolio flows have been volatile [*19*].

Brazil, South America's largest economy, has been affected by the lingering global economic weakness. After growing at a rate of 1.5 percent in 2002, Brazil's economy is estimated to have an annual growth of 0.5 percent in 2003. One of the main factors in this dismal growth has been the continued high level of domestic nominal and real interest rates. Domestic interest rates have remained high because the central bank had to contend with the upsurge of inflation and of inflationary expectations induced both by the large depreciation of the Brazilian currency, the real, in 2002 and by the large injections of liquidity that the central bank undertook a year ago to keep domestic short-term interest rates at unsustainably low levels. As is the case in most Latin American countries, Brazil still needs foreign capital to support stronger domestic economic growth, due to a lack of domestic savings.

Brazil is in a strong position to attract large flows of foreign capital, if it is able to make those investments secure and foreign investors can expect an appropriate return. Thus, President Lula's signals and actions regarding government policy toward private businesses and foreign investors are crucial to securing a steady flow of funds from abroad, which will enable the country to sustain high economic growth over the medium term. Over the 2005 to 2010 period, Brazil's economy is projected to grow at an annual rate of 3.9 percent. Barring any unforeseen negative developments, that growth rate is projected to be maintained over the long run.

In the long term, beyond macroeconomic stability and commitment to sound fiscal and monetary policies, the countries of Central and South America will have to tackle governance issues and attempt to correct severe economic disparities between the wealthy and the poor in the region's societies. They will also need to develop the mature financial markets necessary to generate resources sufficient to allow them to become less dependent on foreign finance, thus allowing investments in physical infrastructure and human capital to be financed domestically [*20*].

In the Middle East, the overarching event in 2002-2003 was the war in Iraq, provoking continued high oil prices. In the rise of uncertainty surrounding the situation in the Persian Gulf in 2002 and early 2003, oil prices surged and oil exporters lifted oil production. Combined with fiscal expansion programs, high oil prices led to an expansion of output growth to 3.2 percent in oil-exporting countries in 2002 [*21*]. Private-sector growth in Saudi Arabia and several other Gulf countries is expected to remain weak as a result of the disruption caused by the war in Iraq, but companies from Saudi Arabia and Kuwait will benefit from subcontracting work associated with the reconstruction of the Iraqi infrastructure.

For 2004, a stronger global growth environment and progress in addressing key regional problems in Iraq and elsewhere still offer the hope that regional real GDP growth in the Middle East will be about 3.7 percent, increasing to a rate of 4.1 percent in 2005, which is expected to be sustained through 2010. According to the IMF, the key policy issue for Middle Eastern countries is accelerating growth to reduce generally high unemployment rates and absorb the rapidly growing labor force. The central issues to be addressed are structural and institutional in nature. The priorities vary across countries but include a reduction in the role of the government, strengthening of institutions and governance, trade liberalization, and diversification away from oil production [*22*].

Africa's aggregate GDP grew by an estimated 3.3 percent in 2003. Better global prospects for growth in 2004 and some recent strengthening in non-oil commodity prices suggest that Africa should be expected to do better in 2004 and 2005, with annual GDP growth projected at 4.4 percent. In the longer run, Africa will continue to face formidable obstacles to growth from low savings and investment rates, limited quantity and quality of infrastructure and human capital, negative perceptions of international investors, and especially HIV/AIDS.

In principle, higher standards of governance and improved policies should encourage higher savings and investment and raise productivity and economic growth in Africa. At the same time, however, it will not be easy for the nations of Africa to overcome the obstacles listed above. Moreover, Africa remains highly dependent on primary commodity exports and thus is exposed to high external volatility [**23**]. Although those factors indicate downside risks to the projections, achieving the moderate improvement projected in the *IEO2004* forecast seems a plausible baseline expectation. For Africa as a whole, average annual GDP growth of 4.0 percent is projected over the 2001 to 2025 period.

Alternative Growth Cases

Expectations for the future rates of economic growth are a major source of uncertainty in the *IEO2004* forecast. To account for the uncertainties associated with economic growth trends, *IEO2004* includes a high economic growth case and a low economic growth case in addition to the reference case. The reference case projections are based on a set of regional assumptions about economic growth paths— measured by GDP—and energy elasticity (the relationship between changes in energy consumption and changes in GDP). The two alternative growth cases are based on alternative assumptions about possible economic growth paths; assumptions about the elasticity of energy demand are held constant, at reference case values (Figure 23).

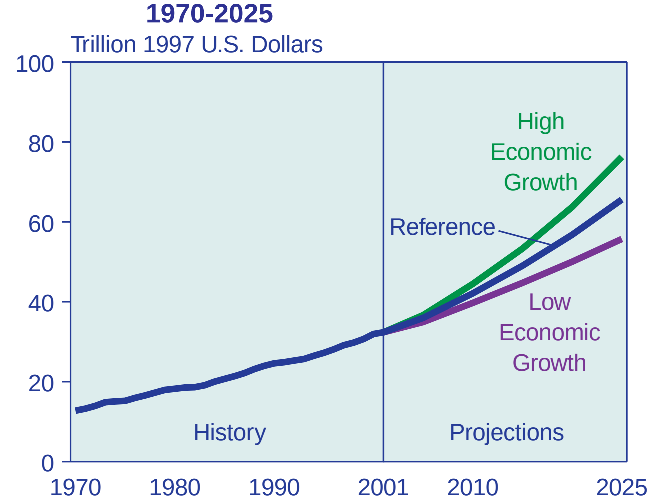
For the high and low economic growth cases, different assumptions are made about the range of possible economic growth rates among the industrial, transitional EE/FSU, and developing economies. For the industrialized countries, 0.5 percentage point is added to the reference case GDP growth rates for the high economic growth case and 0.5 percentage point is subtracted from the reference case GDP growth rates for the low economic growth case. Outside the industrialized world and excluding the former Soviet Union, reference case GDP growth rates are also increased and decreased by 1.0 percentage point to provide the high and low economic growth case estimates.

The FSU suffered a severe economic collapse in the early part of the decade and, until recently, has shown wide variation in its year-to-year economic growth. Between 1990 and 2001, its annual growth rate in GDP has varied from -15 percent in 1992 to +9 percent in 2000. Given this wide range, the FSU nations may be characterized as being a region with considerably more future uncertainty than other regions of the world. As a result, 1.5 percentage points are added and subtracted from the reference case GDP assumptions to derive the high and low macroeconomic forecasts for the FSU region.

The *IEO2004* reference case shows total world energy consumption reaching 623 quadrillion Btu in 2025, with the industrialized world projected to consume 281 quadrillion Btu, the transitional EE/FSU countries 76 quadrillion Btu, and the developing world 266 quadrillion Btu. In the high economic growth case, total world energy use in 2025 is projected to be 710 quadrillion Btu, 87 quadrillion Btu (or 44 million barrels per day oil equivalent) higher than in the reference case (Figure 24). Under the assumptions of the low economic growth case, worldwide energy consumption in 2025 is projected to be 81 quadrillion Btu (40 million barrels per day oil equivalent) lower than in the reference case, at 542 quadrillion Btu. Thus, there is a substantial range of 168 quadrillion Btu, or about one-fourth of the total consumption projected for 2025 in the reference case, between the projections in the high and low economic growth cases.

Corresponding to the range of the energy consumption forecasts, carbon dioxide emissions in 2025 are projected to total 32,032 million metric tons in the low economic growth case (5,092 million metric tons less than the reference case projection of 37,124 million metric tons) and 42,551 million metric tons in the high economic growth case (5,427 million metric tons higher than the reference case projection).

Figure 23. World Gross Domestic Product in Three Economic Growth Cases, 1970-2025



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** Global Insight, Inc., *World Economic Outlook*, Vol. 1 (Lexington, MA, Third Quarter 2004); and EIA, System for the Analysis of Global Energy Markets (2004).

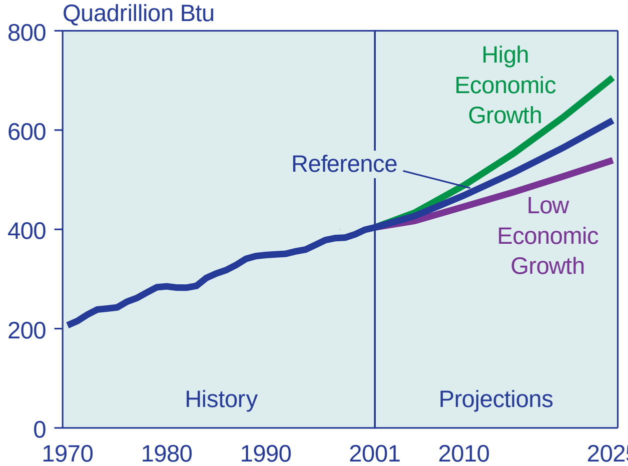
Trends in Energy Intensity

Another major source of uncertainty surrounding long-term forecasts is the relationship of energy use to GDP over time. Economic growth and energy demand are linked, but the strength of that link varies among regions and their stages of economic development. In industrialized countries, history shows the link to be a relatively weak one, with energy demand lagging behind economic growth. In developing countries, demand and economic growth have been more closely correlated in the past, with energy demand growth tending to track the rate of economic expansion.

The historical behavior of energy intensity in the former Soviet Union is problematic. Since World War II, the EE/FSU economies have had higher levels of energy intensity than either the industrialized or the developing countries. In the FSU, however, energy consumption grew more quickly than GDP until 1990, when the collapse of the Soviet Union created a situation in which both income and energy use declined but GDP fell more quickly and, as a result, energy intensity increased. Over the forecast horizon, energy intensity is expected to decline in the region as the EE/FSU nations continue to recover from the economic and social problems of the early 1990s. Still, energy intensity in the EE/FSU region is expected to be more than double that in the developing world and five times that in the industrialized world in 2025 (Figure 25).

The stage of economic development and the standard of living of individuals in a given region strongly influence the link between economic growth and energy demand. Advanced economies with high living standards have a relatively high level of energy use per capita, but they also tend to be economies where per capita energy use is stable or changes very slowly. In the industrialized countries, there is a high penetration rate of modern appliances and motorized personal transportation equipment. To the extent that spending is directed to 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.

Figure 24. World Primary Energy Consumption in Three Economic Growth Cases, 1970-2025

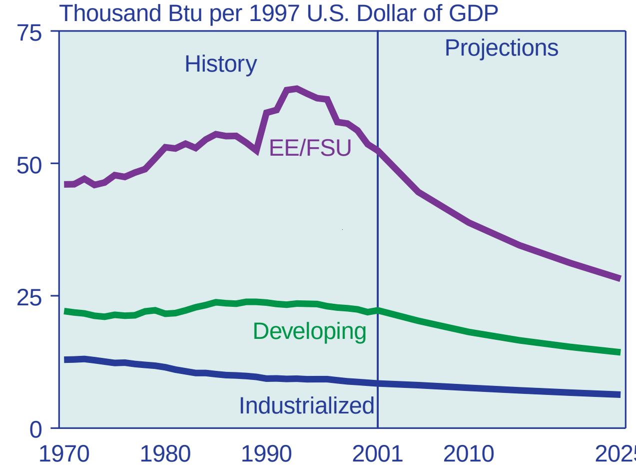


Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

References

1. D.F. Barnes et al., "Tackling the Rural Energy Problem in Developing Countries," *Finance & Development*, Vol. 34, No. 2 (June 1997), pp. 11-15.
2. A. Kirby, "Russia's Climate Tussle Spins On," *BBC News Online* (December 4, 2003).
3. A.C. Revkin, "Into Thin Air: Kyoto Accord May Not Die (or Matter)," *The New York Times* (December 4, 2003), p. A6.
4. The White House, Office of the Press Secretary, "President Announces Clear Skies & Global Climate Change Initiatives" (Press Release, February 14, 2002), web site www.whitehouse.gov/news/releases/2002/02/20020214-5.html.
5. Energy Information Administration, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004); and Global Insight, Inc., *World Overview* (Lexington, MA, September 2003). India's GDP growth rates were adjusted downward, based on the judgment of EIA analysts.

Figure 25. World Energy Intensity by Region, 1970-2020



Sources: **History:** Derived from Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

6. International Monetary Fund, “Economic Prospects and Policy Issues,” in *World Economic Outlook: Public Debt in Emerging Markets* (Washington, DC, September 2003), p. 25, web site www.imf.org/external/pubs/ft/weo/2003/02/.
7. Global Insight, Inc., *World Overview* (Lexington, MA, September 2003), pp. 19-35.
8. M. Mussa, “A Global Growth Rebound: How Strong for How Long?” (Institute for International Economics, September 9, 2003), web site www.iie.com/publications/papers/mussa0903.pdf.
9. International Monetary Fund, “Economic Prospects and Policy Issues,” in *World Economic Outlook: Public Debt in Emerging Markets* (Washington, DC, September 2003), p. 28, web site www.imf.org/external/pubs/ft/weo/2003/02/.
10. United Nations, *World Economic and Social Survey 2003* (New York, NY: United Nations Publications, January 2003), Chapter 1, p. 9, web site www.un.org/esa/policy/wess/.
11. “Moving Forward—If United States Can Keep Pace,” *Washington Post* (November 16, 2003), p. F2.
12. Global Insight, Inc., *Asia and Oceania: Quarterly Review and Outlook* (Lexington, MA, Third Quarter 2003).
13. United Nations, *World Economic and Social Survey 2003* (New York, NY: United Nations Publications, January 2003), Chapter 1, p. 10, web site www.un.org/esa/policy/wess/.
14. Global Insight, Inc., *Asia and Oceania: Quarterly Review and Outlook* (Lexington, MA, Third Quarter 2003), pp. 9-15.
15. World Bank, *Global Economic Prospects 2004: Realizing the Development Promise of the Doha Agenda* (Washington, DC, September 2003), Appendix 1, “Regional Economic Prospects,” web site www.worldbank.org/prospects/gep2004/full.pdf.
16. World Bank, *Global Economic Prospects 2004: Realizing the Development Promise of the Doha Agenda* (Washington, DC, September 2003), Appendix 1, “Regional Economic Prospects,” p. 239, web site www.worldbank.org/prospects/gep2004/full.pdf.
17. International Monetary Fund, “Economic Prospects and Policy Issues,” in *World Economic Outlook: Public Debt in Emerging Markets* (Washington, DC, September 2003), p. 37, web site www.imf.org/external/pubs/ft/weo/2003/02/.
18. “Making a Splash,” *The Economist* (August 7, 2003).
19. United Nations, *World Economic and Social Survey 2003* (New York, NY: United Nations Publications, January 2003), Chapter 1, web site www.un.org/esa/policy/wess/.
20. World Bank, *Global Economic Prospects 2004: Realizing the Development Promise of the Doha Agenda* (Washington, DC, September 2003), Appendix 1, “Regional Economic Prospects,” p. 244, web site www.worldbank.org/prospects/gep2004/full.pdf.
21. World Bank, *Global Economic Prospects 2004: Realizing the Development Promise of the Doha Agenda* (Washington, DC, September 2003), Appendix 1, “Regional Economic Prospects,” p. 253, web site www.worldbank.org/prospects/gep2004/full.pdf.
22. International Monetary Fund, “Economic Prospects and Policy Issues,” in *World Economic Outlook: Public Debt in Emerging Markets* (Washington, DC, September 2003), p. 47, web site www.imf.org/external/pubs/ft/weo/2003/02/.
23. World Bank, *Global Economic Prospects 2004: Realizing the Development Promise of the Doha Agenda* (Washington, DC, September 2003), Appendix 1, “Regional Economic Prospects,” pp. 251-253, web site www.worldbank.org/prospects/gep2004/full.pdf.

World Oil Markets

In the IEO2004 forecast, OPEC export volumes are expected to more than double while non-OPEC suppliers maintain their edge over OPEC in overall production. Prices are projected to rise gradually through 2025 as the oil resource base is further developed.

Throughout most of 2003, crude oil prices remained near the top of the range preferred by producers in the Organization of Petroleum Exporting Countries (OPEC), $22 to $28 per barrel for the OPEC "basket price." OPEC producers continued to demonstrate disciplined adherence to announced cutbacks in production. Throughout 2003, the upward turn in crude oil prices was brought about by a combination of three factors. First, a general strike against the Chavez regime resulted in a sudden loss of much of Venezuela's oil exports. Although the other OPEC producers agreed to increase their production capacities to make up for the lost Venezuelan output, the obvious strain on worldwide spare capacity kept prices high. Second, price volatility was exacerbated by internal conflict in Nigeria. Third, prospects for a return to normalcy in the Iraqi oil sector remained uncertain as residual post-war turmoil continued in Iraq.

Although the labor turmoil in Venezuela has ended and the Nigerian situation has stabilized, world oil prices are expected to remain above $30 per barrel (for West Texas Intermediate crude oil, in nominal dollars) throughout most of 2004, mainly because of low oil inventories, a surge in oil consumption in developing Asia, and the instability in Iraq. A slight softening of oil prices is anticipated in 2005 but is not expected to endure given OPEC's recent successes in market management behavior through production cutbacks. However, OPEC producers might find it more challenging to firm up oil prices over the next few years, given the expected increase in non-OPEC supply. They not only will have to demonstrate discipline within their own ranks but also must convince selected non-OPEC producers of the merits of production restraint. It remains to be seen whether such a coalition of OPEC and non-OPEC producers can demonstrate the restraint necessary to manage the market. Despite evidence that OPEC has achieved some of its price goals in recent years, production cutback strategies have historically had only limited success.

World oil consumption rose in 2003 by about 1.4 million barrels per day, with the industrialized nations accounting for about 55 percent of the increase. Demand in the developing nations rose by 0.7 million barrels per day, and developing Asia accounted for 81 percent of the increase. With the developing Asian economies no longer in recession, their current growth is beginning to show signs of a return to the rapid economic expansion of the early and mid-1990s. Latin America's oil demand continued to show only modest growth. In the former Soviet Union (FSU), where oil demand grew in 2000 for the first time in more than a decade, there was no increase in demand in 2003. In 2004, world oil demand is expected to grow by about 1.7 million barrels per day [***1***].

Historically, OPEC's market management strategies have often ended in failure. A string of successes over the past 5 years have been the result of tight market conditions characterized by low inventory levels and disciplined participation by OPEC members. Currently, spare production capacity worldwide—with the exception of two or three Persian Gulf members of OPEC—is negligible, and OPEC's consensus building is easier as a result. Non-OPEC production is expected to show significant increases in the near future, however, and several OPEC members have announced plans to expand production capacity over the next several years. In an oil market environment with substantial spare production capacity, it may be more difficult for OPEC to achieve unanimity among its members.

Although non-OPEC producers have been somewhat slow in reacting to higher oil prices, there remains significant untapped production potential worldwide, especially in deepwater areas. The lag between higher prices and increases in drilling activity seems to have increased in the aftermath of the low price environment of 1998 and 1999; nevertheless, non-OPEC production increased by 1 million barrels per day in 2002 and by an additional 900 thousand barrels per day in 2003, and it is expected to increase by an impressive 1.4 million barrels per day in 2004. More than one-half of the total increase in non-OPEC production over the next 2 years is expected to come from Russia and Kazakhstan, and most of the remainder is expected to come from the developing economies of the Atlantic Basin (Latin America and West Africa).

Incorporating the recent price turbulence into the construction of an intermediate- to long-term oil market outlook is difficult and raises the following questions: Will prices remain in OPEC's preferred range in response to production cutback strategies, or will the anticipated increase in non-OPEC production temper the price rise? Will the promising indications of robust economic growth be sustained in the developing countries of Asia, or will there be a return to the severe recessions of 1997-1999? Will technology advances guarantee that oil supply development will move forward even if a low world oil price environment returns?

Although oil prices rose by almost $10 per barrel over the course of 2002 and remained high in 2003, with little promise of downward movement in 2004 because of low inventory levels, surging demand in developing Asia, and the situation in Iraq, such developments are not indicative of the trend in the *International Energy Outlook 2004* (*IEO2004*) reference case. In the short term, oil prices are expected to reflect the market uneasiness brought about by the continuing strife in Iraq. From anticipated high levels throughout 2004, oil prices are projected to decline briefly (through 2006), then rise by about 0.7 percent per year to $27 per barrel in 2025 (all prices in 2002 dollars unless otherwise noted). The economic recovery in Asia is almost complete, and demand growth in developing countries throughout the world is expected to be sustained at robust levels. Worldwide oil demand is projected to reach 121 million barrels per day by 2025, requiring an increment to world production capacity of about 44 million barrels per day over current levels. OPEC producers are expected to be the major suppliers of increased production, but non-OPEC supply is expected to remain highly competitive, with major increments to supply coming from offshore resources, especially in the Caspian Basin, Latin America, and deepwater West Africa.

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 natural, political, and economic circumstances. It is well recognized that tensions in the Middle East, for example, could give rise to serious disruptions of normal oil production and trading patterns. On the other hand, significant excursions from the reference price trajectory are not likely to be sustained for long. High real prices deter consumption and encourage the emergence of significant competition from marginal but large sources of oil and other 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 (i.e., economically viable) 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. The *IEO2004* low and high world oil price cases suggest that the projected trends in growth for oil production are sustainable without severe oil price escalation; however, some oil market analysts find this viewpoint overly optimistic, based on what they consider to be a significant overestimation of both proved reserves and ultimately recoverable resources.

Highlights of the *IEO2004* projections for the world oil market are as follows:

- The reference case oil price projection shows high prices persisting from 2003 into 2004 as a result of OPEC's market management strategies, low oil inventories, surging demand in developing Asia, and the post-war strife in Iraq, a brief decline through 2006, and a modest 0.7-percent average annual increase out to 2025.
- Deepwater exploration and development initiatives generally are expected to be sustained worldwide, with the offshore Atlantic Basin emerging as a major future source of oil production in both Latin America and Africa. Technology and resource availability can sustain large increments in oil production capability at reference case prices. The low price environment of 1998 and early 1999 did slow the pace of development in some prospective areas, especially the Caspian Basin region.
- Economic development in Asia is crucial to the long-term growth of oil markets. The projected evolution of Asian oil demand in the reference case would strengthen economic ties between Middle East suppliers and Asian markets.
- Although 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. Competitive forces (especially, production from nonconventional sources) 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 *IEO2004* reference case projections are significant. The post-war strife in Iraq, the international war on terrorism, uncertain economic recovery in developing Asia and Japan, the success of China's economic reforms and its political situation, the potential for continued social unrest in Venezuela, Brazil's impact on other Latin American economies, and economic recovery prospects for the FSU all increase the risk of near-term political and policy discontinuities that could lead to oil market behavior quite different from that portrayed in the projections.
- Total world oil consumption is expected to increase by 1.9 percent per year over the projection period, from 77 million barrels per day in 2001 to nearly 121 million barrels per day in 2025. The transportation sector is the largest component of worldwide oil use today, and it is expected to account for an increasing share of total oil consumption in the future. Oil's

importance in other end-use sectors is likely to decline where other fuels are competitive, such as natural gas, coal, and nuclear, in the electric power sector, but currently there are no alternative energy sources that compete economically with oil for transportation uses. A review of developments in regional transportation sectors is included in this chapter to underscore the increments in oil production required to meet the projected growth in demand for transportation fuels.

World Oil Prices

The world oil price is defined as the annual average U.S. refiner's acquisition cost of imported crude oil. Three distinct world oil price scenarios are represented in *IEO2004*. The reference case represents EIA's current judgment regarding the expected behavior of OPEC producers in the mid-term, adjusting production to keep world oil prices in the $22 to $28 per barrel range. OPEC (particularly, the Persian Gulf nations) is expected to be the dominant supplier of oil in the international market in the mid-term, and its production choices will significantly affect world oil prices. The low world oil price case represents a future market in which all oil production becomes more competitive and plentiful. The high world oil price case represents a more cohesive and market-assertive OPEC, with lower production goals and other nonfinancial (geopolitical) considerations.

The near-term price trajectory in the *IEO2004* reference case is considerably different from that in *IEO2003*. Last year's reference case price path did not fully reflect the upward price pressure in 2003 brought about by the situations in Venezuela, Nigeria, and Iraq. In the longer term, oil prices in both the *IEO2004* and *IEO2003* reference cases are projected to rise gradually from 2005 through 2025, at an average annual rate of 0.7 percent. The price growth projected in both the *IEO2004* and *IEO2003* reference cases reflects the recognition that OPEC has been able to adhere to a production restraint strategy for the purpose of firming up prices. Three possible long-term price paths are shown in Figure 26. In the reference case, projected prices in 2002 dollars reach $27 per barrel in 2025. (In nominal dollars, the reference case price is expected to be around $51 per barrel in 2025.) In the low price case, prices are projected to be $17 per barrel in 2005 and to remain at about that level out to 2025. In the high price case, prices are projected to reach $34 per barrel in 2013 and to be around $35 per barrel in 2025. The leveling off in the high price case results from projected market penetration of alternative energy supplies that could become economically viable at that price (such as liquids from oil sands, natural gas, coal, biofuels, and oil shale).

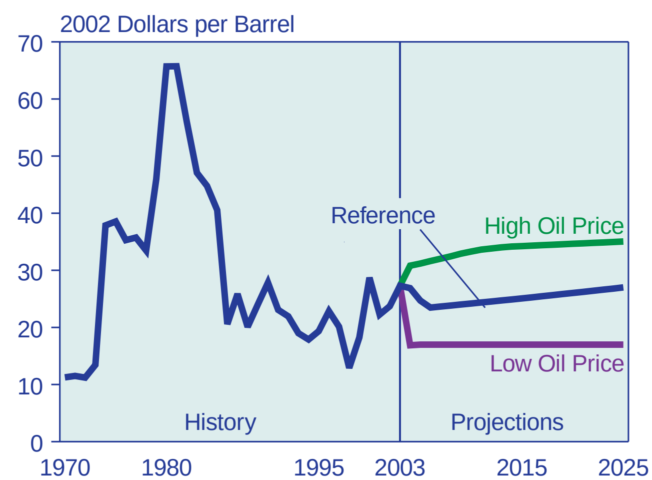
In all the *IEO2004* oil price cases, oil demand is expected to rise significantly over the projection period. The projected increase in oil consumption ranges from a low of 36 million barrels per day in the high price case to a high of 56 million barrels per day in the low price case. There is widespread agreement that resources are not a key constraint on world demand to 2025 (see box on page 37). Rather more important are the political, economic, and environmental circumstances that could shape developments in oil supply and demand.

World Outlook for Oil Use in the Transportation Sector

Energy use in the transportation sector is dominated by petroleum product fuels; and barring any increase in the penetration of new technologies, such as hydrogen-fueled vehicles, alternative fuels are not expected to become competitive with oil before 2025. Thus, the *IEO2004* reference case projection of 2.1-percent average annual growth in the world's total energy use for transportation from 2001 to 2025 (Figure 27) is paralleled by the forecast for transportation oil use.

Energy use for the transportation sector is poised for its strongest growth in developing Asia. China is the key market that will drive regional consumption growth. India is also on a rapid growth path, and the region's mid-sized markets, such as Thailand and Indonesia are projected to post strong growth. In China the number of cars has been growing by 20 percent per year, and the potential growth is almost unlimited. If the present patterns persist, China's car ownership would exceed the U.S. by 2030 [2].

Figure 26. World Oil Prices in Three Cases, 1970-2025



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www. eia.doe.gov/iea/. **Projections:** 2003-2004—EIA, *Short-Term Energy Outlook*, on-line version (April 2004), web site www.eia.doe.gov/emeu/steo/pub/contents.html. 2004-2025—EIA, *Annual Energy Outlook 2004*, DOE/EIA-0383 (2004) (Washington, DC, January 2004).

United States

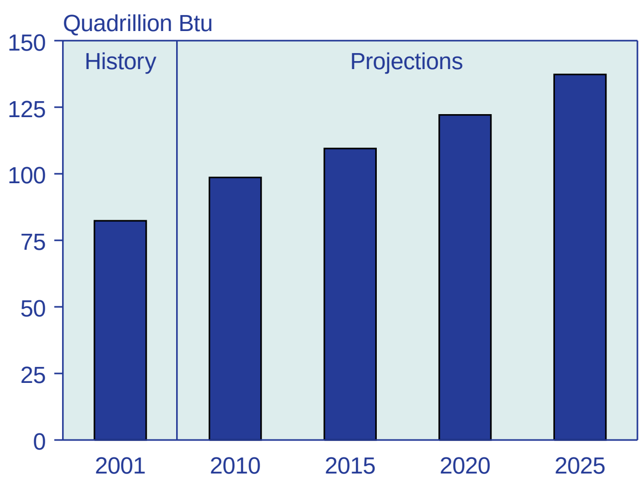
Demand for oil in the United States is projected to increase at an average rate of 1.5 percent per year from 2001 to the end of the forecast, reaching 28.3 million barrels per day in 2025. Demand for energy in the transportation sector is expected to grow rapidly as the result of a projected increase in per capita travel, along with a slower increase in fuel efficiency than was achieved over the past two decades due to projected stable fuel prices and the absence of new efficiency standards. Growth in U.S. energy demand for transportation averaged 2.0 percent per year in the 1970s but was slowed in the 1980s by rising fuel prices and new Federal efficiency standards that led to a slight increase in average vehicle fuel economy. In the *IEO2004* reference case, transportation energy demand in the United States is projected to grow from 26.6 quadrillion Btu in 2001 to 41.2 quadrillion Btu in 2025, and the transportation share of total energy use is projected to increase from 28 percent in 2001 to 30 percent in 2025 (Figure 28).

Fuel economy for the light-duty vehicle stock is projected to improve by 6 percent over the forecast period. Projected low fuel prices and higher personal incomes are expected to increase the demand for larger, more powerful vehicles; however, advanced technologies and materials are expected to provide increased performance and size while improving new vehicle fuel economy. Fuel economy standards for cars are assumed to stay at current levels, and light truck standards are expected to increase from 20.7 miles per gallon in 2001 to 22.2 miles per gallon by 2007 [***3***]. For the stock of freight trucks, fuel economy is projected to increase from 6.0 miles per gallon in 2002 to 6.5 miles per gallon in 2025. A larger gain (22.2 percent) is expected for aircraft.

Non-highway transportation modes accounted for about 20 percent of total U.S. transportation energy use in 2001, and their share is projected to be only 1 percentage point higher in 2025. Fuel consumption by U.S. domestic and international air carriers is projected to increase at an average rate of 1.8 percent per year, from 2.97 quadrillion Btu in 2001 to 4.3 quadrillion Btu in 2025. Energy use by railroad freight carriers is projected to increase by 0.9 percent per year, from 0.50 quadrillion Btu in 2001 to 0.57 quadrillion Btu in 2025, and energy use railroad passenger carriers is projected to increase by 1.8 percent per year, to 0.17 quadrillion Btu in 2025. Energy use by transit buses is projected to increase by 0.4 percent per year, to 0.26 quadrillion Btu in 2025 [***4***].

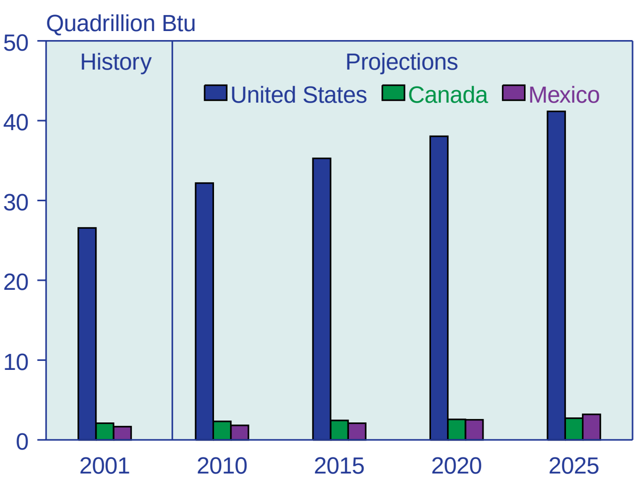
Alternative fuels are projected to displace some light-duty vehicle fuel consumption in 2025, in response to current environmental and State energy legislation intended to reduce oil use, such as the California Low Emission Vehicle Program, which sets sales mandates for low-emission, ultra-low-emission, and zero-emission vehicles [***5***]. Advanced technology vehicles, representing automotive technologies that use alternative fuels or require advanced engine technology, are projected to reach 3.9 million vehicle sales per year in the United States and make up 19 percent of total light-duty vehicle sales in 2025. Alcohol flexible-fueled vehicles are projected to continue to lead advanced technology vehicle sales, at 1.4 million vehicles in 2025. Hybrid electric vehicles, introduced into the U.S. market by Honda and Toyota in 2000, are expected to sell well: 750,000 units

Figure 27. World Transportation Energy Use, 2001-2025



Sources: **2001:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219 (2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **2010-2025:** EIA, System for the Analysis of Global Energy Markets (2004).

Figure 28. Transportation Energy Use in North America, 2001-2025



Sources: **2001:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219 (2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **2010-2025:** EIA, System for the Analysis of Global Energy Markets (2004).

are projected to be sold in 2010, increasing to 1.1 million units in 2025. Sales of turbo direct injection diesel vehicles are projected to increase to 716,000 units in 2010 and 1 million units in 2025 [*6*].

Eighty percent of the advanced technology sales in the forecast are expected to result from Federal and State mandates for fuel economy standards, emissions programs, or other energy regulations. Currently, manufacturers selling alcohol flexible-fueled vehicles receive fuel economy credits that count toward compliance with corporate average fuel economy regulations. In the forecast, the majority of projected gasoline hybrid, fuel cell, and electric vehicle sales result from compliance with low-emission vehicle programs in California, New York, Maine, Vermont, and Massachusetts.

Canada

With the lowest population growth among North American countries, estimated at 0.6 percent per year between 2001 and 2025, Canada's energy demand for transportation is projected to grow relatively slowly, from 2.1 quadrillion Btu in 2001 to 2.7 quadrillion Btu in 2025, and the transportation share of total energy use is projected to fall from 17 percent in 2001 to 15 percent in 2025. Canada's total refinery capacity has declined in the past decade as a result of reduced demand for refined products. The number of retail outlets in Canada has decreased steadily since 1990 [*7*].

Mexico

Oil consumption in Mexico is projected to rise by 2.5 percent per year in the forecast, to 3.5 million barrel per day in 2025. Over the same period, energy for transportation is projected to nearly double, from 1.7 quadrillion Btu in 2001 to 3.2 quadrillion Btu in 2025, and the transportation share of total energy consumption is projected to be 28 percent in 2025. Gasoline used in private cars is expected to account for most of the increase, in addition to some growth in consumption of liquefied petroleum gas (LPG), assuming that LPG will continue to be taxed at a lower rate than gasoline for environmental reasons [*8*].

Western Europe

Energy demand for transportation in Western Europe is projected to grow at a comparatively slow pace, from 15.5 quadrillion Btu in 2001 to 16.7 quadrillion Btu in 2025, and the transportation sector's share of total energy use is projected to decline from 23 percent in 2001 to 21 percent in 2025. Low population growth, high taxes on transportation fuels, and environmental policies are expected to slow the rate of energy demand growth in Western Europe to an average rate of 0.3 percent per year.

Oil is projected to remain Western Europe's largest energy source, with demand increasing by 0.5 percent per year on average from 2001 to 2025. Almost all of the projected increase in demand for oil is expected to be for transportation. Demand for aviation fuel shows the fastest growth among transportation fuels in the forecast, and demand for diesel fuel is projected to increase more rapidly than demand for gasoline, because most countries in the region are expected to keep diesel taxes lower than those for gasoline.

The European Commission has been pushing for deregulation of mass transit systems in the European Union. Some recent European Court of Justice rulings will force hundreds of cities to open their local bus, tram, and subway systems to private competition over the next few years. Deregulation would offer cities across the European Union an opportunity to create more efficient public transit systems [*9*].

Japan

Energy demand for transportation in Japan is projected to grow at an average rate of 0.6 percent per year, from 4.2 quadrillion Btu in 2001 to 4.8 quadrillion Btu in 2025, based primarily on Japan's aging population and low birth rate. The *IEO2004* reference case projects that the Japanese population will shrink by 0.1 percent per year, from 127 million in 2001 to 123 million in 2025.

There were about 53.5 million cars and 19.8 million commercial vehicles in use in Japan in 2001, with an estimated ownership rate of 2.3 persons per car [*10*]. Passenger cars in Japan are subject to nine taxes, imposed on acquisition, ownership, and operation. The taxes are aimed at reducing oil imports and securing government funds for infrastructure projects, such as road maintenance and construction. The taxes amount to $73.6 billion per year, accounting for one-tenth of total government revenues. For environmental reasons, mini-cars are offered a preferential tax rate. In addition to annual registration fees, Japan assesses an annual tax on mini-cars, which in 2000 was equivalent to $58, compared with $278 for large vehicles.

Japan has a mature air transportation infrastructure, with more than 65 commercial airports, 14 of which handle international traffic; however, its airports generally are congested, expensive, and in many cases inefficient. The largest and most important airport is New Japan Narita International, located 41 miles from Tokyo. Although it handles more cargo than any other airport in Asia, it is overcrowded, and efforts to expand it have been opposed by residents and lobbying groups.

Japan also has more than 1,000 ports and harbors, 19 of which are designated as major ports for foreign trade. Kobe, Japan's main port, is the second largest container port in the world.

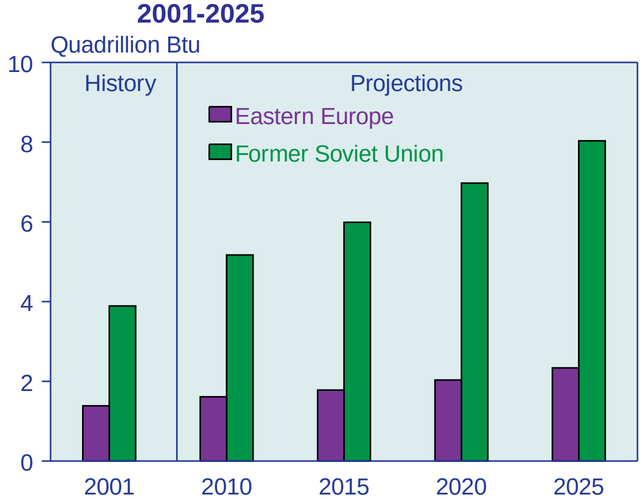
The physical infrastructure of roads, highways, and railroads in Japan is fully developed. Because of high land prices and regulations restricting large stores, Japan's retail stores are generally small, lacking adequate shelf space. As a result, they require frequent stocking by wholesalers using small trucks that can navigate the narrow streets, and there are huge numbers of trucks on urban roads and highways during daytime business hours, causing major traffic jams in urban centers.

Japan leads the global field in alternative fuel technologies, with more than 2,500 electric vehicles currently in use. Japan was also the first market to develop mass-produced hybrid vehicles with gasoline engines and electric motors. Many trucks and city buses use the technology. In addition, there are more than 300,000 LPG-fueled vehicles currently in use, including trucks and city taxis, as well as a number of compressed natural gas (CNG) vehicles. Toyota became the first automaker to debut a hybrid vehicle in 1997 with its Prius model, and it introduced the world's first hybrid minivan, the Estima, in June 2001. Toyota plans to sell 300,000 hybrids per year worldwide by 2005 [*11*].

Australia and New Zealand

Energy demand for transportation in Australia and New Zealand combined is projected to grow at an average rate of 2.0 percent per year, from 1.5 quadrillion Btu in 2001 to 2.4 quadrillion Btu in 2025, and the transportation share of total energy consumption for the two countries is projected to grow from 25 percent in 2001 to 27 percent in 2025. Although road transport is expected to continue to dominate energy use in the transportation sector, led by passenger vehicles in both Australia and New Zealand, continued strong growth is expected for both domestic and international air travel. Oil use for rail transport is projected to grow only slightly, consistent with increased electrification of the rail system and the continued dominance of trucks as the main mode of domestic freight transport [*12*]. In the Australian Northern Territory, the completion of the Alice Springs to Darwin rail link between 2003 and 2005 is expected to increase energy consumption in the rail sector.

Figure 29. Transportation Energy Use in Eastern Europe and the Former Soviet Union, 2001-2025



Sources: **2001:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219 (2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **2010-2025:** EIA, System for the Analysis of Global Energy Markets (2004).

Eastern Europe and the Former Soviet Union

Energy demand in the EE/FSU transportation sector as a whole is projected to grow at an average annual rate of 3.1 percent, from 3.9 quadrillion Btu in 2001 to 8.0 quadrillion Btu in 2025 (Figure 29), led by expanding ownership of private automobiles and an increasing role of trucking in freight transportation. The economies of the EE/FSU countries traditionally have depended heavily on rail transport, an inheritance from the centrally planned system. Slower growth in transportation energy use is projected for Eastern Europe, averaging 2.2 percent per year (from 1.4 quadrillion Btu in 2001 to 2.3 quadrillion Btu in 2025) Nearly all the projected growth in oil consumption for Eastern Europe results from an expected increase in private car ownership.

Developing Asia

China

Energy use for transportation in China is projected to grow by 5.3 percent per year, from 4.1 quadrillion Btu in 2001 to 14.0 quadrillion Btu in 2025 (Figure 30). Virtually all the of the projected increase is for petroleum products, and about two-thirds of the total projected increment in China's oil demand over the forecast period is expected to be for transportation use.

Road transport is expected to be the primary factor in China's growing demand for transportation fuels. China had 4,325 million registered automobiles and 10,212 million registered trucks and buses at the end of 2001 (as compared with 128,714 million registered automobiles and 87,969 million trucks and buses in the United States) [*13*]. Personal travel in China has soared in the past two decades, with passenger miles traveled increasing five-fold [*14*].

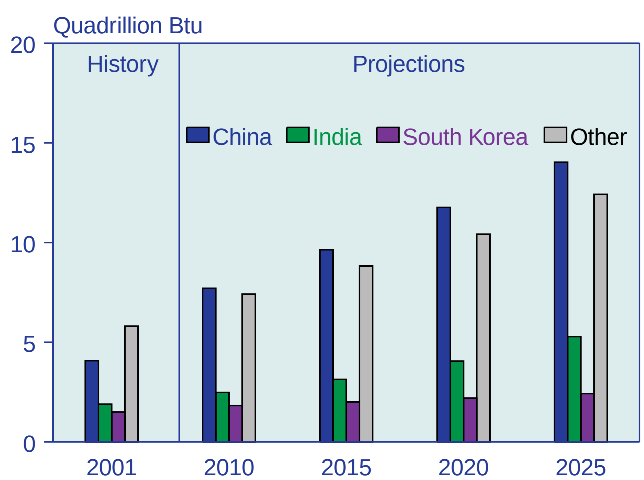
The Chinese passenger car market grew tenfold between 1990 and 2000. In addition, demand for cars exploded in 2002, when a price war was launched by local automakers in expectation of increased import competition after tariffs were lowered by the government following China's entry into the World Trade Organization in December 2001. However, the road system still is failing to keep up with the growth in car use, and major cities are already facing gridlock. The *Beijing Evening News* has reported that fuel consumption per kilometer for cars in China is 10 to 20 percent higher than in developed countries [*15*], and Chinese vehicle emission standards allow cars to emit almost twice as much carbon monoxide and three times as much hydrocarbons and nitrogen oxides as do the U.S. emission standards. Air pollution has been estimated to cost China roughly 5 percent of GDP annually [*16*].

The railway system is the backbone of China's transport network, and the Chinese government plans to spend more than $42 billion to build 4,375 miles of new track from 2001 to 2006 [*17*]. Aviation is the second fastest growing passenger-transport mode. Passenger-miles traveled by air quadrupled in the 1990s, and rising household incomes and commercial activity are expected to result in continued strong growth in air travel. Demand for buses is expected to increase rapidly in China with the extension of expressways in the south and west, and demand for heavy trucks is expected to increase as a result of infrastructure development in preparation for the 2008 Beijing Olympics.

India

India's energy demand for transportation is projected to grow at an average rate of 4.4 percent a year, from 1.9 quadrillion Btu in 2001 to 5.3 quadrillion Btu in 2025, and the transportation sector is expected to account for 20 percent of the country's total energy consumption in 2025. Some of India's transportation infrastructure is well developed by Asian standards, especially the railways (although many rural areas still are largely inaccessible by rail). India has the most extensive railway system in the world, dating back to colonial times. An estimated 1.6 million people are employed by the railway system, making it the world's largest employer [*18*].

Figure 30. Transportation Energy Use in Developing Asia, 2001-2025



Sources: **2001:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219 (2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **2010-2025:** EIA, System for the Analysis of Global Energy Markets (2004).

The Indian automotive industry is also well established, dating back more than 50 years. There were about 4.9 million cars and 6.9 million commercial vehicles in use in India in 2001, with an estimated vehicle ownership rate of 195 persons per car [*19*]. With increased attention on India's polluted cities, the trend in passenger cars and commercial vehicles is becoming more environmentally conscious, with greater emissions restrictions and a surge in CNG-fueled vehicles. In April 2002, the Delhi government pulled 6,000 diesel buses off the roads and purchased 1,000 new CNG-fueled buses.

India's road transport continues to be held back by poverty, urban overcrowding, and the absence of decent roads in many rural areas. The quality of roads, and even highways, is poor by international standards; they are badly maintained, narrow, and highly congested. There are nearly 60,000 fatalities a year in traffic crashes, compared with just over 40,000 in the United States. Recognizing the problem, the Indian government is spending about $12.5 billion to upgrade existing roads and construct new highways [*20*].

South Korea

In South Korea, energy demand for transportation is projected to grow by 2.0 percent per year, from 1.5 quadrillion Btu in 2001 to 2.4 quadrillion Btu in 2025. Its total demand for oil is projected to grow at an average annual rate of growth of 1.3 percent, from 2.1 million barrel per day in 2001 to 2.9 million barrel per day in 2025, much slower than the average of 8.0 percent per year over the past three decades, an indication of the maturity of the South Korean transportation sector. Just over one-half of the projected increase in oil demand is expected in the transportation sector, with much of the remainder in the industrial sector.

The South Korean government plans to allow the sale of diesel-powered cars beginning in January 2005 [*21*]. Under current government policy, diesel fuel is priced at 60 percent of the gasoline price, and thus it is expected that diesel-powered cars will grow in popularity over the forecast period. There were about 9 million cars and 4 million commercial vehicles in use in 2001 in Korea, with an estimated vehicle ownership rate of 5.3 persons per car [*22*].

South Korea has three international airports, including Kimpo, 16 miles from the capital Seoul, which is the largest and the tenth busiest cargo airport in the world and the third busiest in Asia. Air travel is an important component of South Korea's transportation sector, trains and buses are well established, and the Seoul subway system is considered one of the best in the world.

Other Developing Asia

Energy demand for transportation in the other nations of developing Asia is projected to grow from 5.8

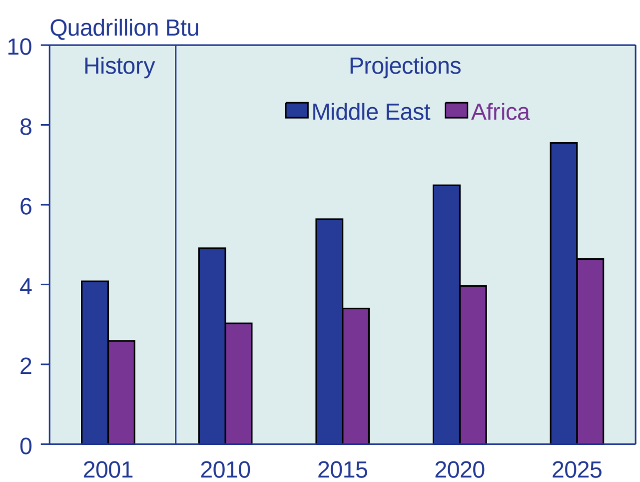
quadrillion Btu in 2001 to 12.4 quadrillion Btu in 2025. The transportation share of total energy use in the region is projected to increase from 24 percent in 2001 to 30 percent in 2025, as national economies continue to mature and rising standards of living result in increased motor transport.

The largest economies in the region are Thailand, Indonesia, Malaysia, Singapore, Taiwan, and Hong Kong. Air traffic within and to the region was hit especially hard during the severe acute respiratory syndrome (SARS) outbreak in 2003, which contributed to a drop in the consumption of jet fuel. SARS weakened Hong Kong's economy, reducing GDP growth in 2003 by an estimated 1.4 percent as consumer spending and tourism declined [*23*]. The impact of the SARS epidemic was temporary, however, and by early 2004 air travel had rebounded. In 2004, Hong Kong's economy is expected to grow by 4.5 percent [*24*].

In Thailand, strong economic growth has increased energy demand for transportation. Diesel fuel consumption is growing quickly, indicating a strong recovery in industrial activity. Jet fuel and kerosene consumption fell during the SARS outbreak but have since recovered. Automobile sales have increased by 30 to 40 percent in each of the past 2 years [*25*].

In Indonesia, weak economic growth, along with a series of price increases for refined products, slowed the growth in demand for transportation fuels in 2003. Malaysia continues to register strong industrial production that is stimulating demand for refined products, although jet fuel demand has yet to recover from a decline during the 2003 SARS scare in the region.

Figure 31. Transportation Energy Use in the Middle East and Africa, 2001-2025



Sources: **2001:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219 (2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **2010-2025:** EIA, System for the Analysis of Global Energy Markets (2004).

In Singapore, bunker fuel oil consumption makes up more than one-half of total oil demand. During 2003, before and during the Iraq war, consumption surged as some tankers preferred to fuel in Singapore and avoid fueling in the Middle East as much as possible.

Middle East

The Middle East region has a relatively small population and is not a major energy consumer but rather an exporter; however, rapid population growth is expected to result in greater demand for transportation energy use in the future. Energy demand for transportation is projected to grow from 4.1 quadrillion Btu in 2001 to 7.5 quadrillion Btu in 2025 (Figure 31).

In percentage terms, the "Asian boom" in oil demand and refinery expansion in the early 1990s has been eclipsed by growth in the Middle East since the late 1990s. From 1973 to 2003, annual growth in demand for oil in the Middle East quadrupled (from 1 percent to 4.3 percent), while the U.S. market remained stagnant at just over 1 percent per year, and Asian markets average 2.5 percent per year [*26*]. Demand for transportation fuels in traditional exporting countries such as Saudi Arabia, Kuwait, Iraq, Oman, the United Arab Emirates, Yemen, and, most notably, Iran made the region a net importer of gasoline in 2003; however, that trend is expected to be reversed by 2010, when planned expansions of refinery capacity come on stream.

Africa

Energy demand for transportation in Africa is projected to grow from 2.6 quadrillion Btu in 2001 to 4.6 quadrillion Btu in 2025. South Africa's economy, the largest in the continent, has been growing strongly for the past few years, helping to sustain total economic growth in the region. The average life expectancy is less than 50 years in most of Africa, and less than 40 years in some of the countries that have been ravaged by AIDS [*27*]. The *IEO2004* reference case assumes that Africa's population will increase by 59 percent from 2001 to 2025 (to 1,292 million), and that economic growth will average 4.0 percent per year, leading to higher demand for energy in the transportation sector.

Central and South America

Economic growth in Central and South America has begun to recover from the downturns in several or the region's major economies from 2000 to 2002, but lingering economic problems are expected to limit growth in transportation energy use for several more years. Brazil, Argentina, and Venezuela, which together account for more than 50 percent of the region's oil demand, had negative growth in oil consumption as result of weak economic performance in 2002, and price decontrols are affecting consumption of transportation fuels in Brazil and Colombia, as liberalized prices float higher with strong crude oil prices. Brazil's gasoline prices rose by 30 percent in local currency terms in 2003, and demand declined by nearly 7 percent. Colombia is also cutting back government subsidies for gasoline and diesel fuel, with full elimination expected by the end of 2006 [*28*].

In the *IEO2004* forecast, energy demand for transportation in the region is projected to grow at an average annual rate of 2.1 percent, from 5.7 quadrillion Btu in 2001 to 9.5 quadrillion Btu in 2025, as a result of rising demand for personal mobility and for transport of commercial goods.

The Composition of World Oil Supply

In the *IEO2004* reference case, world oil supply in 2025 is projected to exceed the 2001 level by about 44 million barrels per day. Increases in production are expected for both OPEC and non-OPEC producers; however, only about 40 percent of the total increase is expected to come from non-OPEC areas. Over the past two decades, the growth in non-OPEC oil supply has resulted in an OPEC 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.

The reference case projects that 60 percent of the increase in petroleum demand over the next two decades will be met by an increase in production by members of OPEC rather than by non-OPEC suppliers. OPEC production in 2025 is projected to be more than 25 million barrels per day higher than it was in 2001 (Figure 32). The *IEO2004* estimates of OPEC production capacity to 2010 are slightly less than those projected in *IEO2003*, reflecting a shift toward non-OPEC supply projects in the recent high price environment. Some analysts suggest that OPEC might pursue significant price escalation through conservative capacity expansion decisions rather than undertake ambitious production expansion programs; however, the projections in this outlook do not assume such views.

Reserves and Resources

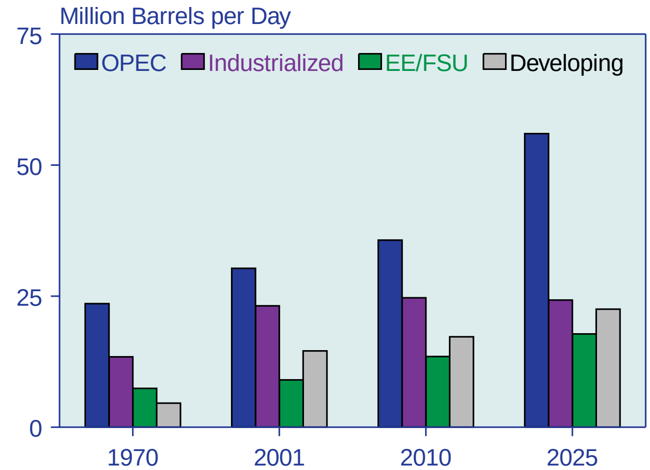
Table 5 shows estimates of the conventional oil resource base by region over the period 1995 to 2025. Proved reserves are taken from the annual assessment of worldwide reserves published by *Oil & Gas Journal* [*29*]. Reserve growth and undiscovered estimates are based on the *World Petroleum Assessment 2000* by the U.S. Geological Survey (USGS). The oil resource base is defined by three categories: proved reserves (oil that has been discovered but not produced); reserve growth (increases in reserves resulting mainly from technological factors that enhance a field's recovery rate); and undiscovered (oil that remains to be found through exploration). The information in Table 5 is derived from current estimates of proved reserves and the USGS mean estimate, an average assessment over a wide range of uncertainty for reserve growth and undiscovered resources. The *IEO2004* oil production forecast is based on the information in Table 5.

Expansion of OPEC Production Capacity

It is generally acknowledged that OPEC members with large reserves and relatively low costs for expanding production capacity can accommodate sizable increases in petroleum demand. In the *IEO2004* reference case, the production call on OPEC suppliers is projected to grow at a robust annual rate of 2.6 percent through 2025 (Table 6 and Figure 33). OPEC capacity utilization is expected to increase sharply after 2001, reaching 90 percent by 2015 and remaining there through 2025.

Amidst enormous uncertainty, Iraq's role in OPEC in the next several years will be of particular interest. In 1999, Iraq expanded its production capacity to 2.8 million barrels per day in order to reach the slightly more than $5.2 billion in oil exports allowed by United Nations Security Council resolutions. The expansion was required because of the low price environment of early 1999. In the *IEO2004* reference case, Iraq is assumed to maintain its current oil production capacity of 3.1 million barrels per day into 2004, and its exports are assumed to generate revenues no greater than those allowed by the United Nations Security Council sanctions. Iraq has indicated a desire to expand its

Figure 32. World Oil Production in the Reference Case by Region, 1970, 2001, 2010, and 2025



Sources: **1970 and 2001:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219 (2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **2010 and 2025:** EIA, System for the Analysis of Global Energy Markets (2004).

Table 5. Estimated World Oil Resources, 1995-2025
(Billion Barrels)

Region and Country	Proved Reserves	Reserve Growth	Undiscovered	Total
Industrialized				
United States	22.7	76.0	83.0	**181.7**
Canada	178.9	12.5	32.6	**224.0**
Mexico	15.7	25.6	45.8	**87.1**
Japan	0.1	0.1	0.3	**0.5**
Australia/New Zealand	3.6	2.7	5.9	**12.1**
Western Europe	18.2	19.3	34.6	**72.1**
Eurasia				
Former Soviet Union	78.0	137.7	170.8	**386.5**
Eastern Europe	1.4	1.5	1.4	**4.2**
China	18.3	19.6	14.6	**52.5**
Developing Countries				
Central and South America	98.8	90.8	125.3	**314.9**
India	5.4	3.8	6.8	**16.0**
Other Developing Asia	11.0	14.6	23.9	**49.5**
Africa	87.0	73.5	124.7	**285.2**
Middle East	726.8	252.5	269.2	**1,248.5**
Total	**1,265.8**	**730.1**	**938.9**	**2,934.8**
OPEC	**869.5**	**395.6**	**400.5**	**1,665.6**
Non-OPEC	**396.3**	**334.5**	**538.4**	**1,269.2**

Note: Resources include crude oil (including lease condensates) and natural gas plant liquids.

Sources: **Proved Reserves as of January 1, 2004:** *Oil & Gas Journal*, Vol. 101, No. 49 (December 22, 2003), pp. 46-47. **Reserve Growth Total and Undiscovered, 1995-2025:** U.S. Geological Survey, *World Petroleum Assessment 2000*, web site http://greenwood. cr.usgs. gov/energy/WorldEnergy/DDS-60. **Estimates of Regional Reserve Growth:** Energy Information Administration, *International Energy Outlook 2002*, DOE/EIA-0484(2002) (Washington, DC, March 2002), p. 32.

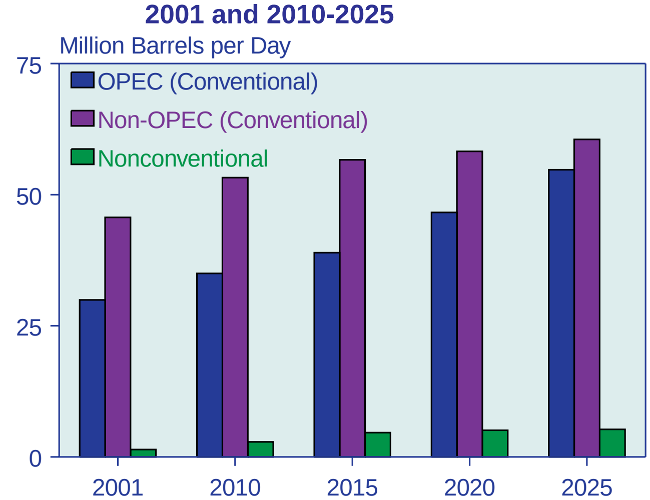
Table 6. OPEC Oil Production, 1990-2025
(Million Barrels per Day)

Year	Reference Case	High Oil Price	Low Oil Price
History			
1990	24.5	—	—
2001	30.3	—	—
Projections			
2010	35.7	28.2	42.1
2015	40.0	29.5	49.3
2020	47.8	35.4	60.1
2025	56.0	42.2	71.2

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

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www. eia.doe.gov/ iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

Figure 33. OPEC, Non-OPEC, and Nonconventional Oil Production in the Reference Case, 2001 and 2010-2025



Sources: **2001:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219 (2001) (Washington, DC, February 2003), web site www.eia.doe.gov/ iea/. **2010-2025:** EIA, System for the Analysis of Global Energy Markets (2004).

Oil Resources in the 21st Century

Early in 2004, two oil market issues captured the attention of market observers. First, Royal Dutch Shell announced that it was revising its reporting of reserves, moving 3.9 billion barrels of oil equivalent from the proved to the probable category. Second, an article in the *New York Times* on February 24 implied that Saudi Arabia's oil fields were in decline, and that the kingdom probably would be unable to expand oil production capacity to meet increasing oil demand. Both of these supply-side issues had a somewhat negative effect on the stock market. The reserve revision by Shell turned out to be a reinterpretation of reporting conventions and had more to do with natural gas than oil; and in an emphatic rebuttal to the *New York Times* article, Saudi Arabia maintained that its oil producers are confident in their ability to sustain significantly higher levels of production capacity well into the middle of this century.[a]

As the above examples demonstrate, whenever the sustainability of the oil resource base comes into question, there are always those eager to warn the world of a looming shortage in oil supplies. Inevitably, the question becomes, "Are we running out of oil?" In April 2000, the U.S. Geological Survey (USGS) released the results of its thorough and methodologically sound assessment of worldwide petroleum resources.[b] The USGS identified at least 3 trillion barrels (mean estimate) of ultimately recoverable conventional oil resources worldwide. The assessment prompted EIA to analyze the long-term world conventional oil supply potential, using alternative assumptions about the levels of ultimately recoverable resources and demand growth.[c] Based on the EIA analysis, all three of the *IEO2004* oil price cases would expect conventional oil to peak closer to the middle than to the beginning of the 21st century.

No one doubts that fossil fuels are subject to depletion, and that depletion leads to scarcity, which in turn leads to higher prices. Resources are defined as "nonconventional" when they cannot be produced economically at today's prices and with today's technology. With higher prices, however, the gap between conventional and nonconventional oil resources narrows. Ultimately, a combination of escalating prices and technological enhancements can transform the nonconventional into the conventional. Much of the pessimism about oil resources has been focused entirely on conventional resources. In the *IEO2004* forecast, nonconventional liquids include production from oil sands, ultra-heavy oils, gas-to-liquids technologies, coal-to-liquids technologies, biofuel technologies, and shale oil. Total nonconventional liquids production in 2025 is projected at 4.1, 5.2, and 8.0 million barrels per day in the low price, reference, and high price cases, respectively. It is anticipated that nonconventional oil resources will act as a buffer against prolonged periods of high oil prices well into the middle of this century, and perhaps well beyond.

[a]M. Abdul Baqi and N. Saleri, *Fifty-Year Crude Oil Supply Scenarios: Saudi Aramco's Perspective* (Washington, DC, February 2004).
[b]U.S. Geological Survey, *World Petroleum Assessment 2000*, web site http://greenwood.cr.usgs.gov/energy/WorldEnergy/DDS-60.
[c]"World Conventional Oil Supply Expected To Peak in 21st Century," *Offshore* (April 2003), p. 90.

production capacity aggressively, to more than 6 million barrels per day, once the sanctions are lifted and the oil sector is deemed safe from terrorist activities. Preliminary discussions of exploration projects have already been held with potential outside investors, including companies from France, Russia, and China. Such a large increase in Iraqi oil exports would offset a significant portion of the price stimulus associated with current OPEC production cutbacks.

Given the requirements for OPEC production capacity expansion implied by the *IEO2004* estimates, much attention has been focused on the oil development, production, and operating costs of individual OPEC producers. With Persian Gulf producers enjoying a reserve-to-production ratio that exceeds 115 years, substantial capacity expansion clearly is feasible.

The average production cost in Persian Gulf OPEC nations is less than $2 per barrel, and the capital investment required to increase production capacity by 1 barrel per day is less than $5,750 [***30***]. Assuming the *IEO2004* low price trajectory, total development and operating costs over the entire projection period, expressed as a percentage of gross oil revenues, would be about 28 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 $12,870 in some member nations; yet those producers can expect cost to revenue ratios of about 46 percent on investments to expand production capacity over the long term, even in the low price case [***31***]. Venezuela has the greatest potential for capacity expansion and could aggressively increase its production capacity by more than 1.0 million barrels per day, to 4.2 million barrels per day by 2005. It is unclear, however, whether the current political climate will support the outside investment required for any substantial expansion of production capacity. Tables D1-D6 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 argue for the pursuit of a relatively aggressive expansion strategy.

In the *IEO2004* forecast, OPEC members outside the Persian Gulf are expected to increase their production potential substantially, despite their higher capacity expansion costs. There is much optimism regarding Nigeria's offshore production potential, although it is unlikely to be developed until the middle to late part of this decade. In addition, increased optimism about the production potential of Algeria, Libya, and Venezuela supports the possibility of reducing the world's dependence on Persian Gulf oil.

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 three decades, as non-OPEC supply became increasingly diverse. North America dominated non-OPEC supply in the early 1970s, the North Sea and Mexico evolved as major producers in the 1980s, and much of the new production in the 1990s has come from the developing countries of Latin America, West Africa, the non-OPEC Middle East, and China. In the *IEO2004* reference case, non-OPEC supply from proved reserves is expected to increase steadily, from 46.7 million barrels per day in 2001 to 64.6 million barrels per day in 2025 (Table 7).

There are several important differences between the *IEO2004* production profiles and those published in *IEO2003*:

- The U.S. production decline is somewhat more severe in the *IEO2004* projections as a result of higher exploration and production costs, coupled with lower expected finding rates in the National Petroleum Reserve-Alaska.
- The growth in Russian oil production is more optimistic in the *IEO2004* forecast, as Russian companies in alliance with Western service companies continue to surprise industry experts with productivity increases in West Siberia.
- Production of nonconventional liquids (especially those from oil sands and ultra-heavy oils) is considerably more optimistic in *IEO2004* as production costs decline and markets evolve.
- In the *IEO2004* projections, Caspian output is expected to exceed 3.1 million barrels per day in 2010 and increase steadily thereafter. However, there still remains a great deal of uncertainty about export routes from the Caspian Basin region.

In the *IEO2004* forecast, the decline in North Sea production is slowed as a result of the implementation of strategies for redeveloping mature fields. Production from Norway, Western Europe's largest producer, is expected to peak at about 3.6 million barrels per day in 2006 and then gradually decline to about 2.5 million barrels per day by the end of the forecast period with the maturing of some of its larger and older fields. The United Kingdom sector is expected to produce about 2.2 million barrels per day through 2010, followed by a decline to 1.4 million barrels per day in 2025.

Two non-OPEC Persian Gulf producers are expected to increase output gradually over the first half of this decade. Enhanced recovery techniques are expected to increase current output in Oman by more than 190,000 barrels per day, with only a gradual production decline anticipated after 2010. Current oil production in Yemen is expected to increase by at least 50,000 barrels per day in the next several years, and those levels could show a slight increase throughout the forecast period. Syria is expected to hold its production flat throughout this decade, but little in the way of new resource potential will allow anything except declining production volumes out to 2025.

Oil producers in the Pacific Rim are expected to increase their production volumes significantly as a result of enhanced exploration and extraction technologies. India is expected to show some modest production increase

Table 7. Non-OPEC Oil Production, 1990-2025
(Million Barrels per Day)

Year	Reference Case	High Oil Price	Low Oil Price
History			
1990	42.2	—	—
2001	46.7	—	—
Projections			
2010	55.4	58.4	54.0
2015	60.2	64.1	58.1
2020	62.1	67.6	59.4
2025	64.6	70.5	61.3

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

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

early in this decade and only a modest decline in output thereafter. Deepwater fields offshore from the Philippines have resulted in an improved reserve picture; by the end of the forecast period, production is expected to exceed 60,000 barrels per day. Vietnam is still viewed with considerable optimism regarding long-term production potential, although exploration activity has been slower than originally hoped. Output levels from Vietnamese fields are expected to exceed 375,000 barrels per day by 2015.

Australia has continued to make additions to its proved reserves, and it is possible that Australia could exceed 800 thousand barrels per day in oil production by the end of this decade. Malaysia shows little potential for any significant new finds, and its output is expected to peak at around 750,000 barrels per day in this decade and then gradually decline to less than 700,000 barrels per day by 2025. Papua New Guinea continues to add to its reserve posture and is expected to achieve production volumes approaching 120,000 barrels per day by the end of this decade, followed by only a modest decline over the remainder of the forecast period. Exploration and test-well activity have pointed to some production potential for Bangladesh and Burma, but significant output is not expected until after 2010.

Oil producers in Central and South America have significant potential for increasing output over the next decade. Brazil became a million barrel per day producer in 1999, with considerable production potential waiting to be tapped. Brazil's production is expected to rise throughout the forecast period and to top 3.9 million barrels per day by 2025. Colombia's current economic downturn and civil unrest have delayed development of its upstream sector, but its output is expected to top 640,000 barrels per day within the decade and continue to show modest increases for the remainder of the forecast period. In both countries, the oil sector would benefit significantly from the creation of a favorable climate for foreign investment.

Argentina is expected to increase its production volumes by at least 60,000 barrels per day over the next 3 years, and by the end of the decade it could possibly to become a million barrel per day producer. Although the current political situation in Ecuador is in transition, there is still optimism that Ecuador will increase production by more than 450,000 barrels per day over the forecast period.

Several West African producers (Angola, Cameroon, Chad, Congo, Equatorial Guinea, Gabon, and Ivory Coast) are expected to reap the benefits of substantial exploration activity, especially if current price levels persist. Angola is expected to become a million barrel per day producer sometime over the next several years. Given recent excellent exploration results, Angola could produce volumes of up to 3.4 million barrels per day well into the later years of the forecast period. The other West African producers with offshore tracts are expected to increase output by up to 750,000 thousand barrels per day for the duration of the forecast.

North African producers Egypt and Tunisia produce mainly from mature fields and show little promise of adding to their reserve posture. As a result, their production volumes are expected to decline gradually throughout the forecast. In East Africa, Sudan is expected to produce significant volumes by the end of this decade and could exceed 500,000 barrels per day by the end of the forecast period. Eritrea, Mauritania, Sao Tome and Principe, Somalia, and South Africa also have some resource potential, but they are not expected to produce significant amounts until after 2010.

In North America, moderately declining U.S. output is expected to be balanced by significant production increases in Canada and Mexico. Canada's conventional oil output is expected to decrease by about 500,000 barrels per day over the next 20 years, but an additional 2.5 million barrels per day is expected in nonconventional output from oil sands projects. Mexico is expected to adopt energy policies that will encourage the efficient development of its vast resource base. Expected production volumes in Mexico exceed 4.2 million barrels per day by the end of the decade and continue to increase by another 500,000 barrels per day by the end of the forecast period.

With higher oil prices projected, oil production in the FSU is expected to exceed 11.0 million barrels per day by 2005, due in large part to the more optimistic outlook for investment in Russia. The long-term production potential for the FSU is still regarded with considerable optimism, especially for the resource-rich Caspian Basin region. The *IEO2004* reference case shows FSU output exceeding 17.2 million barrels per day in 2025, implying export volumes exceeding 10 million barrels per day. In China, oil production is expected to decline slightly, to about 3.4 million barrels per day in 2025. China's import requirements are expected to be as large as its domestic production by 2011 and to continue growing as its petroleum consumption increases.

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 sensitivity to changes in the world oil price. A critical component of the forecasting methodology is the constraint placed on the exploration and development of non-OPEC undiscovered resources. For the purpose of the three *IEO2004* price cases, no more than 15, 30, and 45 percent of the mean United States Geological Survey estimate of non-OPEC undiscovered oil is assumed to be developed over the forecast period in the low price, reference, and high price cases, respectively. In all the oil price cases, OPEC producers are assumed to be the source of the required residual supply. Tables D1-D6 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 stagnate or decline gradually in response to resource constraints. The relatively insignificant cost of developing oil resources in 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 several periods of relatively low prices, non-OPEC production has risen every year since 1993, adding more than 5.8 million barrels per day between 1993 and 2001.

It is expected that non-OPEC producers will continue to increase output, producing an additional 8.7 million barrels per day by 2010. Three factors are generally given 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.

Worldwide Petroleum Trade in the Reference Case

In 2001, industrialized countries imported 16.1 million barrels of oil per day from OPEC producers (Table 8). Of

Table 8. Worldwide Petroleum Trade in the Reference Case, 2001 and 2025
(Million Barrels per Day)

	Importing Region								
	Industrialized				Nonindustrialized				
Exporting Region	North America	Western Europe	Asia	Total	Pacific Rim	China	Rest of World	Total	Total Exports
					2001				
OPEC									
Persian Gulf	2.9	2.7	4.1	**9.7**	4.8	0.9	1.5	**7.2**	**16.9**
North Africa	0.4	2.0	0.0	**2.3**	0.2	0.0	0.0	**0.2**	**2.6**
West Africa	0.9	0.6	0.0	**1.5**	0.7	0.0	0.1	**0.8**	**2.2**
South America	1.8	0.2	0.2	**2.2**	0.1	0.0	0.3	**0.4**	**2.6**
Asia	0.1	0.0	0.3	**0.4**	0.2	0.0	0.0	**0.2**	**0.7**
Total OPEC	**6.1**	**5.5**	**4.6**	**16.1**	**6.0**	**0.9**	**1.9**	**8.8**	**24.9**
Non-OPEC									
North Sea	0.6	4.5	0.0	**5.2**	0.0	0.0	0.0	**0.0**	**5.2**
Caribbean Basin	0.6	0.1	0.0	**0.7**	0.1	0.0	0.1	**0.1**	**0.8**
Former Soviet Union	0.2	3.6	0.3	**4.2**	0.2	0.0	0.1	**0.3**	**4.5**
Other Non-OPEC	5.5	3.6	1.2	**10.3**	3.7	1.1	5.7	**10.5**	**20.8**
Total Non-OPEC	**6.9**	**11.8**	**1.6**	**20.4**	**4.0**	**1.1**	**5.8**	**11.0**	**31.4**
Total Petroleum Imports	**13.0**	**17.3**	**6.2**	**36.5**	**10.0**	**2.0**	**7.8**	**19.7**	**56.3**
					2025				
OPEC									
Persian Gulf	5.8	4.5	5.9	16.3	9.4	5.7	4.9	20.1	36.4
North Africa	0.5	3.1	0.1	3.6	0.8	0.3	0.5	1.6	5.3
West Africa	1.6	1.1	0.3	2.9	1.9	0.5	0.2	2.6	5.6
South America	3.9	0.1	0.4	4.3	0.1	0.0	0.4	0.6	4.9
Asia	0.1	0.0	0.3	0.4	1.5	0.1	0.2	1.9	2.3
Total OPEC	**11.9**	**8.8**	**6.9**	**27.6**	**13.8**	**6.6**	**6.3**	**26.8**	**54.4**
Non-OPEC									
North Sea	0.7	3.4	0.0	4.2	0.3	0.0	0.2	0.5	4.7
Caribbean Basin	1.6	0.5	0.2	2.3	0.6	0.0	0.8	1.4	3.7
Former Soviet Union	0.5	4.7	0.6	5.7	0.7	1.7	1.5	3.8	9.6
Other Non-OPEC	6.8	3.0	0.4	10.1	4.2	0.3	2.5	6.9	17.1
Total Non-OPEC	**9.5**	**11.6**	**1.2**	**22.3**	**5.7**	**2.0**	**5.0**	**12.7**	**35.0**
Total Petroleum Imports	**21.4**	**20.4**	**8.1**	**49.9**	**19.5**	**8.6**	**11.4**	**39.5**	**89.4**

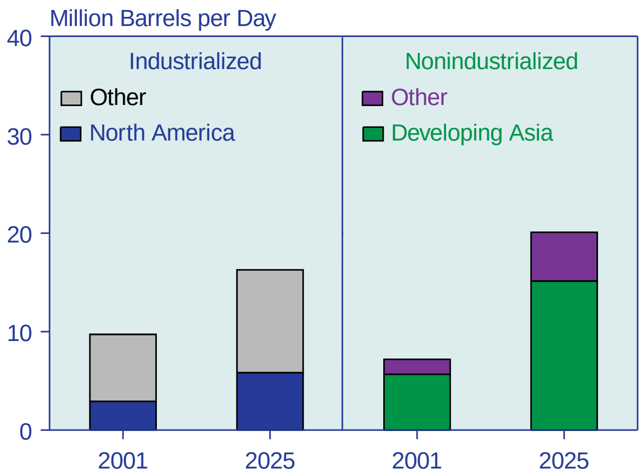
Notes: Totals may not equal sum of components due to independent rounding.
Sources: **2001:** Energy Information Administration (EIA), Energy Markets and Contingency Information Division. **2025:** EIA, Office of Integrated Analysis and Forecasting, IEO2004 WORLD Model run IEO2004.B25 (2004).

that total, 9.7 million barrels per day came from the Persian Gulf region. Oil movements to industrialized countries represented almost 65 percent of the total petroleum exported by OPEC member nations and almost 58 percent of all Persian Gulf exports. By the end of the forecast period, OPEC exports to industrialized countries are estimated to be about 11.5 million barrels per day higher than their 2001 level, and more than half the increase is expected to come from the Persian Gulf region.

Despite such a substantial increase, the share of total petroleum exports that goes to the industrialized nations in 2025 is projected to be almost 9 percent below their 2001 share, and the share of Persian Gulf exports going to the industrialized nations is projected to fall by about 13 percent. The significant shift expected in the balance of OPEC export shares between the industrialized and developing nations is a direct result of the 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 more than 18.0 million barrels per day over the forecast period, with three-fourths of the increase going to the developing countries of Asia. China, alone, is likely to import about 6.6 million barrels per day from OPEC by 2025, virtually all of which is expected to come from Persian Gulf producers.

North America's petroleum imports from the Persian Gulf are expected to double over the forecast period (Figure 34). At the same time, more than one-half of total North American imports in 2025 are expected to be from Atlantic Basin producers and refiners, with significant increases expected 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.

Figure 34. Imports of Persian Gulf Oil by Importing Region, 2001 and 2025



Sources: **2001:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **2025:** EIA, Office of Integrated Analysis and Forecasting, IEO2004 WORLD Model run IEO2004.B25 (2004).

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 dependence on Persian Gulf oil. The developing countries of the Pacific Rim are expected to almost double their total petroleum imports between 2001 and 2025.

Worldwide crude oil distillation refining capacity was about 81.9 million barrels per day at the beginning of 2002. To meet the projected growth in international oil demand in the reference case, worldwide refining capacity would have to increase by more than 40 million barrels per day by 2025. 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, especially transportation fuels.

Other Views of Prices and Production

Several oil market analysis groups produce world oil price and production forecasts. Table 9 compares the *IEO2004* world oil price projections with similar forecasts from the International Energy Agency (IEA), Petroleum Economics, Ltd. (PEL), Petroleum Industry Research Associates (PIRA), Energy and Environmental Analysis, Inc. (EEA), Natural Resources Canada (NRCan), Global Insight, Inc. (GII), Deutsche Bank AG (DB), National Petroleum Council (NPC), Strategic Energy & Economic Research (SEER), and the Centre for Global Energy Studies (CGES).

The collection of forecasts includes a wide range of price projections, based on the volatility of the world oil markets. In particular, oil prices have fluctuated widely since the late 1990s, first tumbling as a result of the Asian economic recession of 1997-1998, then climbing with the region's subsequent recovery (see Figure 26). High oil prices followed the ability of OPEC to maintain production quotas in 2000, which supported sustained high prices throughout the year. Oil prices collapsed in mid- to late 2001 as a result of decreases in demand that accompanied the global economic slowdown and the aftermath of the September 11 terrorist attacks but recovered during 2002 as a result of unrest in the Middle East, oil supply disruptions in Venezuela and Nigeria, and low storage levels in the United States. By the first quarter of 2003 oil prices had neared $35 per barrel (nominal dollars), and they remained near or above the $30 per barrel level throughout the year and into the first part of 2004.

The *IEO2004* price projections are generally at the high end of the spectrum of price forecasts across the 2010-2025 time period, with only two exceptions: PIRA's $26.70 price forecast for 2015 is higher than the *IEO2004* estimate of $25.07 (Table 9); and the IEA price estimate of $27.96 for 2025 is higher than the *IEO2004* reference case projection of $27.00. It should be noted that IEA did not publish a price projection for 2015 or 2025 in its *World Energy Outlook 2002*; however, it states that "prices are assumed to rise in a linear fashion after 2010," from $21.75 per barrel in 2010 to $30.03 per barrel in 2030. A simple interpolation results in oil prices in 2015 of about $23.82 per barrel and in 2025 of $27.96 per barrel, placing the IEA prices below the *IEO2004* estimate in 2015 but above the *IEO2004* estimate in 2025.

The PEL and CGES price forecasts for 2020 are the only two instances in which a price forecast falls below the *IEO2004* low world oil price scenario. Both forecasters expect world oil prices in the mid-term to stay at a flat, nominal $25 per barrel over the mid-term forecast, which translates to $15.60 per barrel in fixed 2002 dollars. If the PEL and CGES series are omitted, the range of prices among the remaining series for 2020 is $8.02, with *IEO2004* at the high end of the range ($26.02 per barrel) and NPC at the low end ($18.00 per barrel). At the end of the forecast period, in 2025, the uncertainty among the forecasters as measured by the difference between highest and lowest expected prices is $9.96 per barrel, with the range defined by the IEA ($27.96 per barrel) and NPC ($18.00 per barrel) forecasts.

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

Table 9. Comparison of World Oil Price Projections, 2010-2025
(2002 Dollars per Barrel)

Forecast	2010	2015	2020	2025
IEO2004				
Reference Case	24.17	25.07	26.02	27.00
High Price Case	33.27	34.23	34.63	35.03
Low Price Case	16.98	16.98	16.98	16.98
IEO2003 Reference Case	24.28	25.01	25.77	26.89
GII	22.26	22.93	23.85	24.77
IEA	21.75	23.82	25.89	27.96
PEL	21.27	18.41	15.60	—
PIRA	23.90	26.70	—	—
NRCan	22.57	22.57	22.57	—
DB	18.43	18.41	18.16	18.26
EEA	20.33	19.84	19.36	—
NPC	18.00	18.00	18.00	18.00
SEER	19.86	20.88	22.49	24.53
CGES	21.27	18.41	15.60	—

Notes: *IEO2004* and *IEO2003* projections are for average landed imports to the United States. PIRA, NRCan, SEER, and NPC projections are for West Texas Intermediate crude oil at Cushing. GII, DB, and EEA projections are for composite refiner acquisition prices. IEA projections are for IEA crude oil import price. PEL projections are for Brent crude oil.

Sources: ***IEO2004*:** Energy Information Administration, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004). ***IEO2003*:** Energy Information Administration, *Annual Energy Outlook 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003). **GII:** Global Insight, Inc., *Global Petroleum Outlook, Winter 2003*-2004 (Lexington, MA, January 2004), p. 41. **IEA:** International Energy Agency, *World Energy Outlook 2002* (Paris, France, September 2002). **PEL:** Petroleum Economics, Ltd., *World Long Term Oil and Energy Outlook* (London, United Kingdom, April 2003), p. 71. **PIRA:** PIRA Energy Group, *Retainer Client Seminar* (New York, NY, October 2003), Table II-3. **NRCan:** Natural Resources Canada, *Canada's Energy Outlook, 1996-2020*, Annex C2 (Ottawa, Ontario, Canada, April 1997) (reaffirmed in August 2003). **DB:** Deutsche Banc AG, "World Oil Supply and Demand Estimates," e-mail from Adam Sieminski (March 1, 2004). **EEA:** Energy and Environmental Analysis, Inc., EEA Compass Service: October 2003 Base Case. **NPC:** National Petroleum Council, *Assumptions for the NPC Natural Gas Study* (Washington, DC, October 2003). **SEER:** Strategic Energy & Economic Research, Inc., *2003 Energy Outlook* (Winchester, MA, 2003). **CGES:** Centre for Global Energy Studies, *Annual Oil Market Forecast and Review 2003* (London, UK, January 2003), p. 164.

OPEC oil production and (2) the timing of an expected increase in EE/FSU oil production. The views about the rate of supply increases to come from the former Soviet Union vary strongly among the forecasters and are key to explaining the differences between the series.

High world oil prices, in excess of $25 per barrel, that have been sustained since mid-2002 have helped sustain the economic recovery of Russia—currently the largest oil producer in the EE/FSU region. Higher investment in Russia's oil sector over the past several years and the interest of foreign companies in participating in the upstream projects in Russia and the other oil-rich former Soviet republics has no doubt influenced the thinking on how fast oil production may grow in the EE/FSU. In 2002, the EE/FSU region as a whole accounted for about 12 percent of total world oil supply. In the *IEO2004* reference case projection, the EE/FSU share of world supply rises to 15 percent in 2020 before declining to 14 percent by 2025 (Table 10). DB is much more bullish about the EE/FSU production potential in the early years of the forecast, expecting EE/FSU supply to rise quickly to account for 17 percent of world supply in 2010 and then drop to 15 percent in 2025. IEA is the least optimistic about growth potential in the region; its projected share for the EE/FSU grows to 14 percent in 2010 but falls to 13 percent in 2020.

The forecasts that provide projections through 2020 (*IEO2004*, DB, GII, IEA, and PEL) expect OPEC to

Table 10. Comparison of World Oil Production Forecasts

Forecast	Percent of World Total			Million Barrels per Day			
	OPEC	EE/FSU	Other Non-OPEC	OPEC	EE/FSU	Other Non-OPEC	Total
History							
2002	38	12	50	29.7	9.6	38.6	**77.9**
Projections							
2010							
IEO2004	39	14	46	35.7	13.1	42.3	**91.1**
GII	38	16	49	33.0	13.6	42.7	**88.4**
IEA[a]	40	14	39	35.9	12.7	35.1	**88.9**
PEL	38	15	45	33.5	12.8	39.5	**88.0**
PIRA	35	16	50	31.3	14.1	45.3	**90.7**
DB	39	17	42	34.7	15.1	37.6	**89.4**
2015							
IEO2004	40	15	45	40.0	15.1	45.1	**100.2**
GII	43	15	45	40.4	14.1	43.1	**94.9**
PEL	43	15	40	40.6	14	38.2	**95.2**
PIRA	38	16	46	37.2	15.4	45.6	**98.2**
DB	44	17	37	42.4	17.0	35.7	**97.3**
2020							
IEO2004	43	15	42	47.8	16.1	46.0	**110.0**
GII	47	15	42	48.4	15.1	43.2	**103.7**
IEA[a]	48	13	31	50.2	13.9	31.8	**104.1**
PEL	48	15	35	48.9	15.0	35.7	**102.2**
DB	47	17	34	48.8	17.7	35.7	**104.7**
2025							
IEO2004	46	14	39	56.0	17.3	47.2	**120.6**
GII	51	14	36	58.2	16.1	41.2	**116.9**
DB	49	15	34	56.0	17.3	38.9	**115.1**

[a]In the GII projections, EE/FSU includes only Russia.

[b]IEA total supply numbers include processing gains and unconventional oil. As a result, regional percentages do not add to 100.

Note: IEA, GII, PEL, and DB report processing gains separately from regional production numbers. As a result, the percentages attributed to OPEC, EE/FSU, and Other Non-OPEC do not add to 100.

Sources: ***IEO2004*:** Energy Information Administration, System for the Analysis of Global Energy Markets (2004). **GII:** Global Insight, Inc., *Global Petroleum Outlook, Winter 2003*-2004 (Lexington, MA, January 2004), p. 40. **IEA:** International Energy Agency, *World Energy Outlook 2002* (Paris, France, September 2002), p. 96. **PEL:** Petroleum Economics, Ltd., *World Long Term Oil and Energy Outlook* (London, United Kingdom, April 2003), Table 4. **PIRA:** PIRA Energy Group, *Retainer Client Seminar* (New York, NY, October 2003). **DB:** Deutsche Banc AG, "World Oil Supply and Demand Estimates," e-mail from Adam Sieminski (March 1, 2004).

provide incremental production of between 18 and 20 million barrels per day between 2002 and 2020 (Table 10). There is more variation in expectations among these five forecasts for the "other" non-OPEC suppliers. GII expects other suppliers to provide increases of 5 million barrels per day and *IEO2004* expects an increase of 7 million barrels per day, whereas IEA expects declines of 7 million barrels per day—and PEL and DB expect declines of 3 million barrels per day—in production from other non-OPEC sources. IEA, DB, and PEL expect the "other" non-OPEC share of world oil supply to fall precipitously over the forecast period. The "other" share falls from 39 percent in 2010 to 31 percent in 2020 in the IEA forecast, from 45 percent in 2010 to 35 percent in 2020 in the PEL forecast, and from 42 percent in 2010 to 34 percent in 2020 in the DB forecast. Over the 2010-2020 period, *IEO2004* and GII foresee a much slower decline in the share of "other" supplies, on the order of 4 to 7 percentage points.

References

1. Energy Information Administration, *Short-Term Energy Outlook*, March 2004 on-line version, web site www.eia.doe.gov/emeu/steo/pub/contents.html.
2. FACTS Inc., *Asia-Pacific Databook 1: Supply, Demand and Prices* (Honolulu, HI, Fall 2003), p. 3, web site www.factsinc.net/products/databooks.shtml.
3. Federal Register, (Washington, DC) Volume 68, No. 66, Monday, April 7, 2003, pp.16868-16900.
4. Energy Information Administration, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table A7, p. 144, web site www.eia.doe.gov/oiaf/aeo/.
5. Energy Information Administration, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), p. 13, web site www.eia.doe.gov/oiaf/aeo/.
6. Energy Information Administration, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), web site www.eia.doe.gov/oiaf/aeo/.
7. World Markets Research Centre, "Country Report: Canada" (January 30, 2004), web site www.wmrc.com.
8. International Energy Agency, *World Energy Outlook 2002* (Paris, France, September 2002), p. 164, web site www.worldenergyoutlook.org.
9. M. Jorss, B. Wiesman, and C. Wolff, *The McKinsey Quarterly* (Fourth Quarter, 2003).
10. Central Intelligence Agency, *World Factbook*, web site www.cia.gov/cia/publications/factbook; and The Society of Motor Manufacturers and Traders Limited, *SMMT World Automotive Statistics 2002*, web site www.autoindustry.co.uk/statistics.
11. World Markets Research Centre, "Automotive Sector Analysis: Japan" (September 23, 2003), web site www.wmrc.com.
12. Australian Bureau of Agricultural and Resource Economics, *Australian Energy: National and State Projections to 2019-20* (Canberra, Australia, June 2003), pp. 28-30, web site www.abareconomics.com.
13. S.C. Davis and S.W. Diegel, *Transportation Energy Data Book: Edition 23*, ORNL-6970 (Oak Ridge, TN: Oak Ridge National Laboratory October 2003), Tables 3.1 and 3.2, web site www-cta.ornl.gov/data/Index.html.
14. International Energy Agency, *World Energy Outlook 2002* (Paris, France, September 2002), web site www.worldenergyoutlook.org.
15. *Beijing Evening News* (November 10, 2003), web site www.ben.com.cn.
16. "The Great Car Crush," *Far Eastern Economic Review* (November 27, 2003), web site www.feer.com.
17. World Markets Research Centre, "Automotive Sector Analysis: China" (September 23, 2003), web site www.wmrc.com.
18. World Markets Research Centre, "Automotive Sector Analysis: India" (September 23, 2003), web site www.wmrc.com.
19. Central Intelligence Agency, *World Factbook*, web site www.cia.gov/cia/publications/factbook; and The Society of Motor Manufacturers and Traders Limited, *SMMT World Automotive Statistics 2002*, web site www.autoindustry.co.uk/statistics.
20. World Markets Research Centre, "Automotive Sector Analysis: India" (September 23, 2003), web site www.wmrc.com.
21. FACTS Inc., *Asia-Pacific Databook 1: Supply, Demand and Prices* (Honolulu, HI, Fall 2003), web site www.factsinc.net/products/databooks.shtml.
22. Central Intelligence Agency, *World Factbook*, web site www.cia.gov/cia/publications/factbook; and The Society of Motor Manufacturers and Traders Limited, *SMMT World Automotive Statistics 2002*, web site www.autoindustry.co.uk/statistics.
23. N.C. Leung, J. Penhirin, and L.A. Yee, "Securing Hong Kong's Future," *The McKinsey Quarterly*, 2003 No. 4, p. 1, web site www.mckinseyquarterly.com.
24. Business Monitor International, *Emerging Markets Monitor* (January 12, 2004), web site www.businessmonitor.com.
25. FACTS Inc., *Asia-Pacific Databook 1: Supply, Demand and Prices* (Honolulu, HI, Fall 2003), web site www.factsinc.net/products/databooks.shtml.

26. FACTS Inc., "Middle East Products: Iran Affects the Regional Balance," *FACTS Energy Advisory*, No. 287 (January 2004), web site www.factsinc.net/products/energy_oil_reports.shtml.

27. J. Sach, "A Rich Nation, a Poor Continent," *New York Times* (July 9, 2003).

28. Cambridge Energy Research Associates, *Refined Products Watch* (Cambridge, MA, Winter 2004), p. 29, web site www.cera.com.

29. "A Worldwide Look at Reserves and Production," *Oil & Gas Journal*, Vol. 100, No. 49 (December 22, 2003), pp. 46-47.

30. DRI/McGraw-Hill, *Oil Market Outlook* (Lexington, MA, July 1995), Table 1, p. 10.

31. Energy Information Administration, *Oil Production Capacity Expansion Costs for the Persian Gulf*, DOE/EIA-TR/0606 (Washington, DC, February 1996).

Natural Gas

Natural gas is the fastest growing primary energy source in the IEO2004 forecast. Consumption of natural gas is projected to increase by nearly 70 percent between 2001 and 2025, with the most robust growth in demand expected among the developing nations.

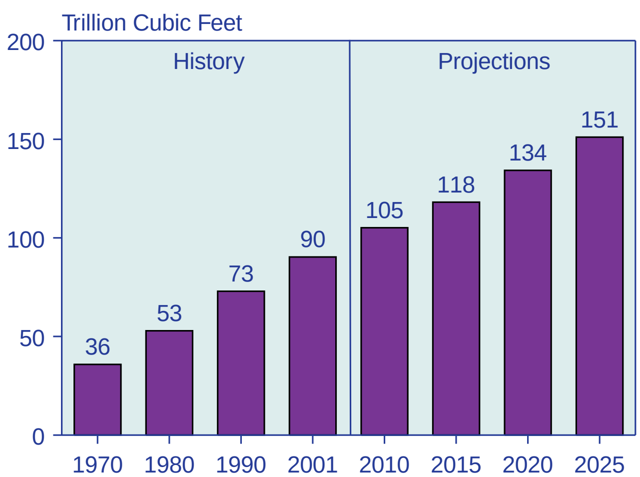
Natural gas is expected to be the fastest growing component of world primary energy consumption in the *International Energy Outlook 2004* (*IEO2004*) reference case. Consumption of natural gas worldwide is projected to increase by an average of 2.2 percent annually from 2001 to 2025, compared with projected annual growth rates of 1.9 percent for oil consumption and 1.6 percent for coal. Natural gas consumption in 2025, at 151 trillion cubic feet, is projected to be nearly 70 percent higher than the 2001 total of 90 trillion cubic feet (Figure 35). The natural gas share of total energy consumption is projected to increase from 23 percent in 2001 to 25 percent in 2025.

The most robust growth in natural gas demand is expected among the nations of the developing world, where overall demand is projected to increase by an average of 2.9 percent per year from 2001 to 2025 in the reference case. Natural gas use in the developing world in 2025 is projected to be double the 2001 level (Figure 36). Most of that increase is expected to be for electricity generation. In the industrialized countries, where natural gas markets are more mature, consumption of natural gas is projected to increase by an average of 1.8 percent per year from 2001 to 2025, with the largest increment projected for North America, at 13 trillion cubic feet (Figure 37).

IEO2004 also includes projections for natural gas production (Table 11), which are new to this year's forecast. The largest increase in production is projected for the Middle East—from 8.3 trillion cubic feet in 2001 to 18.8 trillion cubic feet in 2025. The smallest increase is projected for the industrialized countries—from 39.3 trillion cubic feet in 2001 to 46.8 trillion cubic feet in 2025, an average increase of 0.7 percent per year over the forecast period.

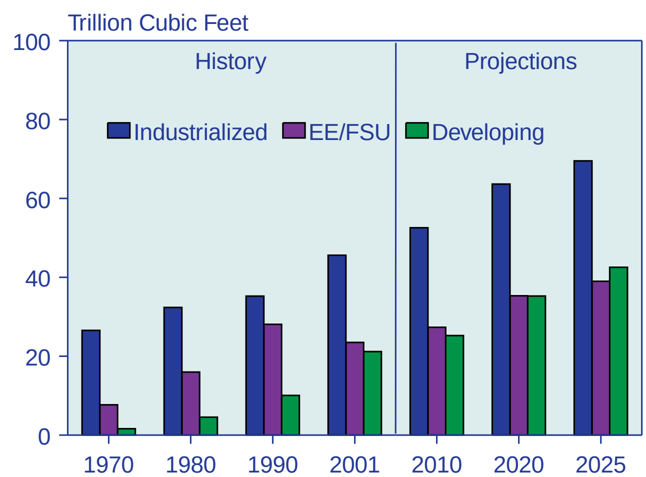
The disparity between the increase expected for natural gas consumption in the industrialized nations and the much smaller increase expected for their gas production indicates that they will rely on other parts of the world for more than 30 percent of their natural gas supply in 2025. In the developing world, gas production is expected to exceed consumption by 16.3 trillion cubic feet in 2025; and in the former Soviet Union, production is projected to exceed consumption by 11.7 trillion cubic feet. As a result, those two regions are expected to be the major source of exports to the rest of the world.

Figure 35. World Natural Gas Consumption, 1970-2025



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

Figure 36. Natural Gas Consumption by Region, 1970-2025



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

The amount of natural gas traded across international borders continues to grow, having increased from 19 percent of the world's consumption in 1995 to 23 percent in 2002 [*1*]. Pipeline exports grew by 46 percent between 1995 and 2002, and trade in liquefied natural gas (LNG) grew by 62 percent. In 2002, the Middle East accounted for 22 percent of the world's international LNG trade and 6 percent of international trade in natural gas. Qatar accounted for 56 percent of the gas exported from the Middle East in 2002.

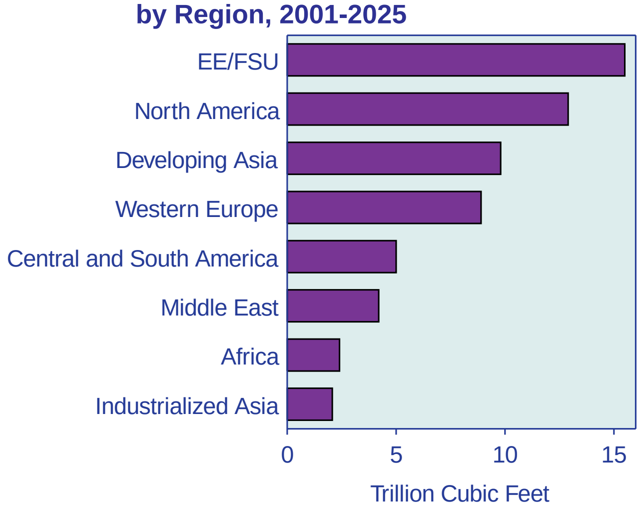
The increases in world natural gas consumption projected in the *IEO2004* reference case will require bringing new gas resources to market, and a number of international pipelines are either planned or already under construction. In addition, because many of the natural gas assets of the developing world are remote from major consuming markets ("stranded"), much of the increment in international trade is expected to be in the form of LNG. The fact that many sources of natural gas are far from demand centers, coupled with cost decreases throughout the LNG chain, has made LNG increasingly competitive, contributing to the expectation of strong worldwide growth in LNG trade.

The economics of transporting natural gas to demand centers currently depends on the market price, and the pricing of natural gas is not as straightforward as the pricing of oil. Almost 60 percent of the world's oil consumption is supplied by imports, whereas natural gas markets tend to be more isolated, with prices varying considerably from country to country. In Asia and Europe, LNG markets are more strongly influenced by oil product prices than by natural gas prices. As the use and trade of natural gas continue to grow, it is expected that pricing mechanisms will continue to evolve, facilitating international trade and paving the way for a global natural gas market.

Reserves and Resources

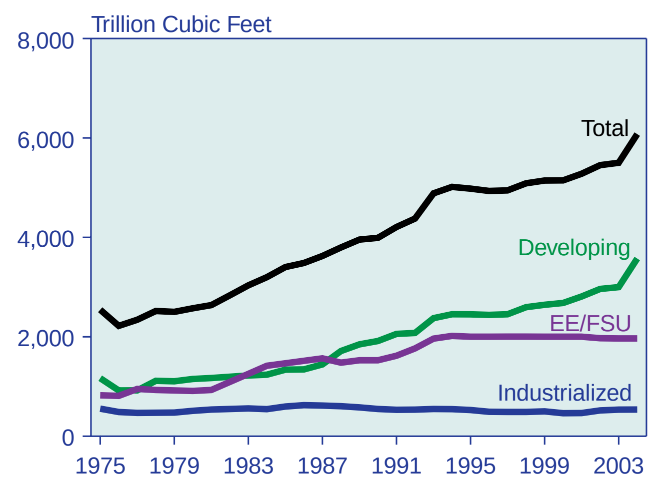
Since the mid-1970s, world natural gas reserves have generally trended upward each year (Figure 38). In 2004, worldwide reserve estimates increased for the ninth consecutive year. As of January 1, 2004, proved world natural gas reserves, as reported by *Oil & Gas Journal*,[9] were estimated at 6,076 trillion cubic feet—575 trillion cubic feet (10 percent) more than the estimate for 2003 [**2**]. The developing world accounted for virtually all the increase in proved reserves. Qatar, where the estimate of proved gas reserves grew from 508 trillion cubic feet for 2003 to 910 trillion cubic feet for 2004, accounted for most of the increment. Smaller but still substantial increases in estimated gas reserves were reported for Iran (an increase of 128 trillion cubic feet) and Nigeria (35 trillion cubic feet). Almost three-quarters of the world's natural gas reserves are located in the Middle East and Eastern Europe and the former Soviet Union (EE/FSU) (Figure 39), with Russia, Iran, and Qatar combined accounting for about 58 percent of the total

Figure 37. Increases in Natural Gas Consumption by Region, 2001-2025



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

Figure 38. World Natural Gas Reserves by Region, 1975-2004



Sources: **1975-1993:** "Worldwide Oil and Gas at a Glance," *International Petroleum Encyclopedia* (Tulsa, OK: PennWell Publishing, various issues). **1994-2004:** *Oil & Gas Journal* (various issues).

[9] Proved reserves, as reported by the *Oil & Gas Journal*, are estimated quantities that can be recovered at current price levels, using the production technology available now. Figures reported for Canada and the former Soviet Union, however, include reserves in the "probable" category. Natural gas reserves reported by the *Oil & Gas Journal* are compiled from voluntary survey responses and do not always reflect the most recent changes. Significant gas discoveries made during 2003 are not likely to be reflected in the reported reserves.

(Table 12). Reserves in the rest of the world are fairly evenly distributed on a regional basis.

In the industrialized world, reserves increased by 0.7 trillion cubic feet between 2003 and 2004. While North America recorded growth of 8.6 trillion cubic feet, Western Europe's reserves declined by 6.1 trillion cubic feet. In North America, reserves in Mexico increased by 6.2 trillion cubic feet in 2004, after they had been reduced by more than 50 percent in 2003 following Mexico's adoption of the U.S. Securities and Exchange Commission definitions for reserves [*3*]. In Western Europe, the decrease in reserves is attributed to production in 2003. In the EE/FSU, reserves contracted by 0.4 trillion cubic feet, entirely attributable to a revision of the reserve estimate for Croatia.

Despite high rates of increase in natural 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 60.7 years [*4*]. Central and South America has a reserves-to-production ratio of 68.8 years, the FSU 75.5 years, and Africa 88.9 years. The Middle East's reserves-to-production ratio exceeds 100 years.

The U.S. Geological Survey (USGS) periodically assesses the long-term production potential of worldwide petroleum resources (oil, natural gas, and natural gas liquids). According to the most recent USGS estimates, released in the *World Petroleum Assessment 2000*, a significant volume of natural gas remains to be discovered. The mean estimate for worldwide undiscovered gas is 4,258

Table 11. World Natural Gas Production by Region, 2001-2025
(Trillion Cubic Feet)

Region/Country	2001	Projections				Average Annual Percent Change, 2001-2025
		2010	2015	2020	2025	
Industrialized Countries						
North America	**27.6**	**29.6**	**30.6**	**32.8**	**33.6**	**0.8**
United States[a]	19.7	20.5	21.6	23.8	24.0	0.8
Canada	6.6	7.6	7.5	7.1	7.5	0.5
Mexico	1.3	1.5	1.6	1.9	2.1	2.0
Western Europe	**10.2**	**9.0**	**9.0**	**8.9**	**9.8**	**-0.2**
Industrialized Asia	**1.5**	**2.3**	**3.0**	**3.2**	**3.4**	**3.5**
Japan	0.1	0.1	0.1	0.1	0.1	-1.0
Australia/New Zealand	1.4	2.3	2.9	3.1	3.4	3.7
Total Industrialized	**39.3**	**40.9**	**42.6**	**44.9**	**46.8**	**0.7**
EE/FSU						
Former Soviet Union	25.7	30.2	34.9	39.6	44.5	2.3
Eastern Europe	0.9	0.9	0.8	0.8	0.8	-0.5
Total EE/FSU	**26.6**	**31.0**	**35.7**	**40.4**	**45.3**	**2.2**
Developing Countries						
Developing Asia	**8.8**	**10.2**	**11.2**	**13.1**	**15.4**	**2.4**
China	1.1	1.6	1.9	2.3	3.1	4.5
India	0.8	0.9	0.9	1.2	1.5	2.6
South Korea	0.0	0.0	0.0	0.0	0.0	—
Other Developing Asia	6.9	7.7	8.3	9.6	10.8	1.9
Middle East	**8.3**	**9.8**	**12.1**	**15.6**	**18.8**	**3.5**
Africa	**4.6**	**8.1**	**9.9**	**11.9**	**14.1**	**4.8**
Central and South America	**3.6**	**5.5**	**7.1**	**8.6**	**10.6**	**4.6**
Total Developing	**25.2**	**33.5**	**40.2**	**49.2**	**58.9**	**3.6**
Total World	**91.1**	**105.5**	**118.5**	**134.5**	**151.0**	**2.1**

[a]Includes the 50 States and the District of Columbia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding.

Sources: **2001:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

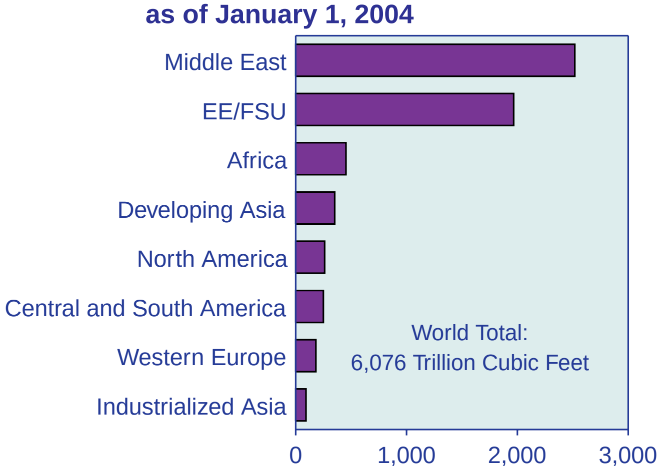
trillion cubic feet (Figure 40), which is approximately double the worldwide cumulative consumption forecast in *IEO2004*. Of the total natural gas resource base, an estimated 3,000 trillion cubic feet is in "stranded" reserves, usually located too far away from pipeline infrastructure or population centers to make transportation of the natural gas economical. Of the new natural gas resources expected to be added over the next 25 years, reserve growth accounts for 2,347 trillion cubic feet. More than one-half of the mean undiscovered gas estimate is expected to come from the FSU, the Middle East, and North Africa; and about one-third (1,169 trillion cubic feet) is expected to come from a combination of North, Central, and South America. It is estimated that about one-fourth of the undiscovered natural gas reserves worldwide are in undiscovered oil fields.

Table 12. World Natural Gas Reserves by Country as of January 1, 2004

Country	Reserves (Trillion Cubic Feet)	Percent of World Total
World	**6,076**	**100.0**
Top 20 Countries	**5,449**	**89.7**
Russia	1,680	27.6
Iran	940	15.5
Qatar	910	15.0
Saudi Arabia	231	3.8
United Arab Emirates	212	3.5
United States	187	3.1
Algeria	160	2.6
Nigeria	159	2.6
Venezuela	148	2.4
Iraq	110	1.8
Indonesia	90	1.5
Australia	90	1.5
Malaysia	75	1.2
Norway	75	1.2
Turkmenistan	71	1.2
Uzbekistan	66	1.1
Kazakhstan	65	1.1
Netherlands	62	1.0
Canada	59	1.0
Egypt	59	1.0
Rest of World	**628**	**10.3**

Source: "Worldwide Look at Reserves and Production," *Oil & Gas Journal*, Vol. 101, No. 49 (December 22, 2003), pp. 46-47.

Figure 39. World Natural Gas Reserves by Region as of January 1, 2004



Source: "Worldwide Look at Reserves and Production," *Oil & Gas Journal*, Vol. 101, No. 49 (December 22, 2003), pp. 46-47.

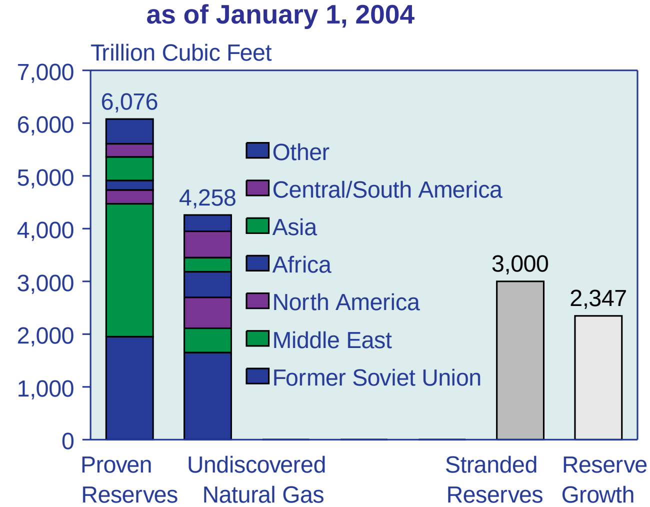
Although the United States has produced more than 40 percent of its total estimated natural gas endowment and carries less than 10 percent as remaining reserves, in the rest of the world reserves have been largely unexploited. Outside the United States, the world has produced less than 10 percent of its total estimated natural gas endowment and carries more than 30 percent as remaining reserves.

Regional Activity

North America

Natural gas consumption in North America is projected to grow at an average annual rate of 1.6 percent between 2001 and 2025 in the *IEO2004* reference case (Figure 41). The highest growth rate in the region—an average annual rate of 3.9 percent—is projected for Mexico, where demand is projected to more than double over the forecast period, from 1.4 trillion cubic feet in 2001 to

Figure 40. World Natural Gas Resources by Region as of January 1, 2004



Source: U.S. Geological Survey, *World Petroleum Assessment 2000*, web site http://greenwood.cr.usgs.gov/energy/WorldEnergy/DDS-60; "Worldwide Look at Reserves and Production," *Oil & Gas Journal*, Vol. 101, No. 49 (December 22, 2003), pp. 46-47; and Energy Information Administration estimates.

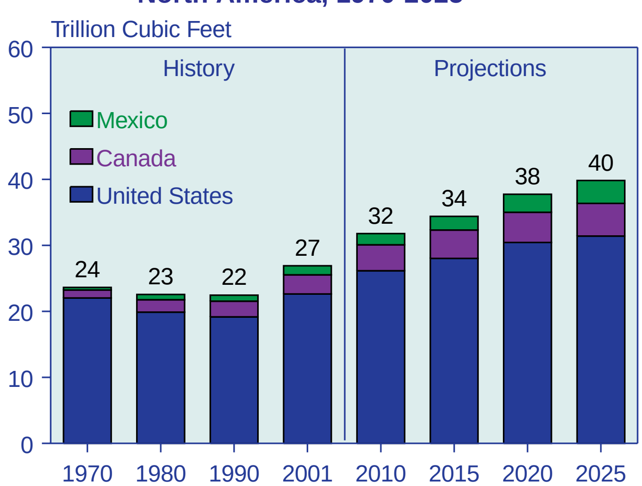
3.5 trillion cubic feet in 2025. Canada's natural gas consumption is projected to increase at an average rate of 2.2 percent per year, increasing by 70 percent over the forecast period.

The United States is by far the largest consumer of natural gas in North America, with consumption projected at 31.4 trillion cubic feet in 2025. Growth in U.S. natural gas use is expected to be strong in the early years of the forecast but to slow after 2020, when projected higher prices erode the advantage of natural gas over coal for electricity generation. As a result, even with continued growth in other sectors, overall consumption of natural gas in the United States is projected to increase at an average annual rate of only 1.4 percent.

The North American natural gas market is tightly integrated, with Canada supplying the bulk of U.S. imports and the United States supplying imports to Mexico. That trade structure is expected to change, however, as LNG imports from other regions begin to play a more prominent role. Imports of LNG into the United States are projected to surpass pipeline imports from Canada by 2015, and LNG imports into Mexico are projected to reduce Mexico's dependence on the United States as early as 2007.

At present, North America produces approximately as much natural gas as it consumes. In 2010, however, the region's consumption is projected to exceed its production by 2 trillion cubic feet, and the gap between production and consumption is projected to increase to almost 5 trillion cubic feet in 2020 and 6 trillion cubic feet in 2025. LNG from other regions will be needed to bridge the gap.

Figure 41. Natural Gas Consumption in North America, 1970-2025



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

United States

Although the United States holds only 3.1 percent of the world's natural gas reserves, it consumed more than any other country in 2001, and its natural gas production was exceeded only by Russia's. With U.S. production projected to grow more slowly than its consumption, it is expected to import more natural gas, most of which is expected to be in the form of LNG.

Until 2001, the United States had only two active receiving terminals for LNG, at Everett, Massachusetts, and Lake Charles, Louisiana. When domestic spot market prices for natural gas climbed above $10 per thousand cubic feet in the winter of 2001, however, plans were announced for the reopening of mothballed LNG terminals in Maryland (Cove Point) and Georgia (Elba Island), and plans for the construction of additional new facilities were discussed. The Cove Point and Elba Island terminals were reopened in 2001 and 2003, respectively. In addition, four new LNG terminals are expected to open on the U.S. Atlantic and Gulf Coasts between 2007 and 2010. The first new LNG terminal in more than 20 years is projected to open on the Gulf Coast in 2007, and another facility, expected to serve Florida, is projected for construction in the Bahama Islands [***5***], with the gas to be transported through an underwater pipeline to Florida (Figure 42).

Total net imports are projected to supply 21 percent of total U.S. natural gas consumption in 2010 (5.5 trillion cubic feet) and 23 percent in 2025 (7.2 trillion cubic feet), compared with recent historical levels of around 15 percent. Nearly all of the increase in net imports, from 3.5 trillion cubic feet in 2002, is expected to consist of LNG. LNG imports already have doubled from 2002 to 2003, based on preliminary estimates that show LNG gross imports at 540 billion cubic feet in 2003, compared with 228 billion cubic feet in 2002. Strong growth in LNG is expected to continue throughout the forecast period, with LNG's share of net imports growing from less than 5 percent in 2002 to 39 percent (2.2 trillion cubic feet) in 2010 and 66 percent (4.8 trillion cubic feet) in 2025 [***6***].

Existing U.S. LNG plants are expected to be at, or close to, full capacity by 2007, importing 1.4 trillion cubic feet annually, and new plants are projected to import a total of 812 billion cubic feet in 2010. In addition, a new terminal in Baja California, Mexico, is expected to start moving gas into Southern California in 2007, with volumes reaching 180 billion cubic feet by 2008. Additional capacity in Baja California is expected to be added in 2012, increasing annual deliveries into Southern California to 370 billion cubic feet per year from 2014 through 2025. Other new terminals are expected to be constructed in the Mid-Atlantic and New England regions by 2016, and significant additional capacity is expected along the Gulf Coast by 2025, including expansions of existing terminals and construction of new ones. Imports into new

Gulf Coast terminals are projected to total nearly 2.5 trillion cubic feet in 2025 [7].

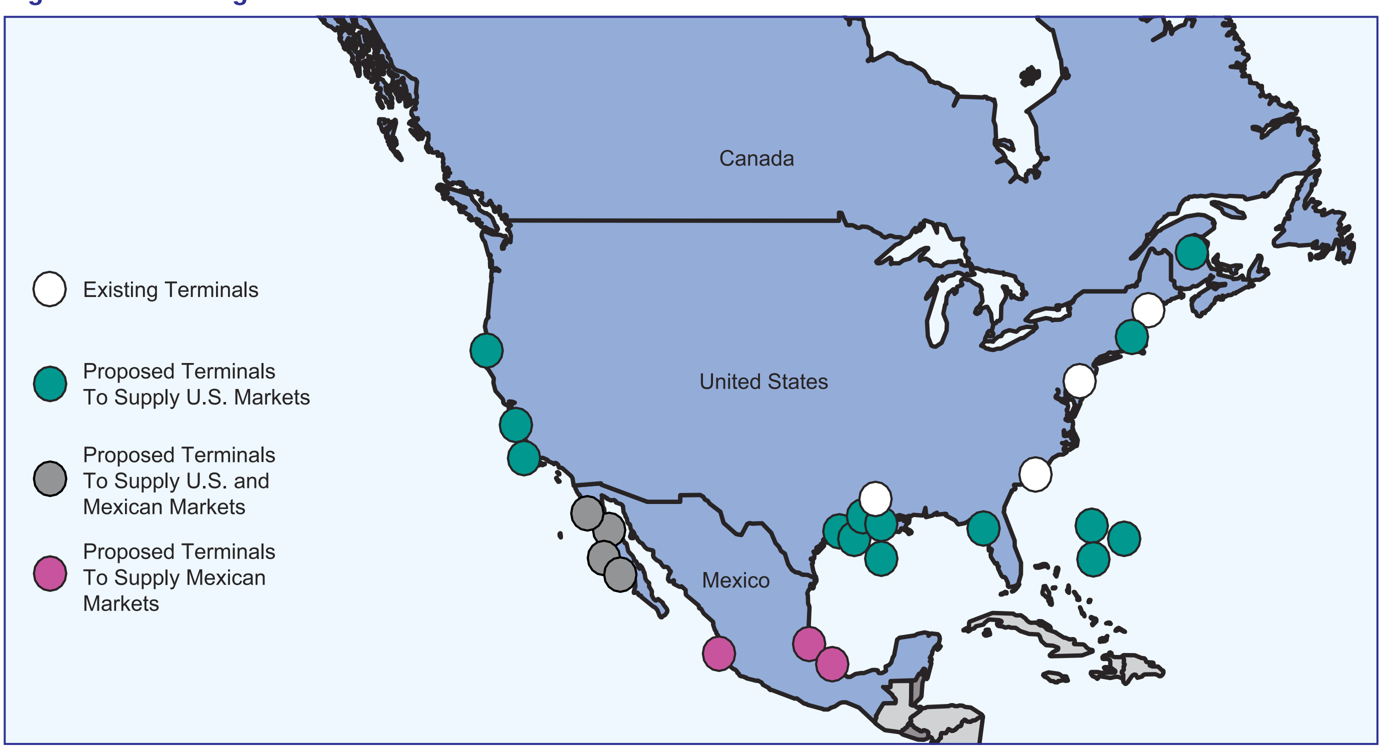
As of August 2002, there were 16 active proposals to construct new LNG regasification terminals in North America to serve U.S. markets (or partially serve, as in the case of three proposed terminals in Baja California, Mexico), with total annual capacity slightly over 5 trillion cubic feet. As of December 1, 2003, there were 32 active proposals for new terminals: 21 in the United States, 4 in Baja California, Mexico (to serve both Mexico and U.S. markets), 2 in Mexico (to serve Mexican markets exclusively), 3 in the Bahamas (to serve U.S. markets), and 2 in Canada (to serve Canada and possibly also U.S. markets). Three proposals to construct terminals in the onshore Gulf of Mexico have been filed with the U.S. Federal Energy Regulatory Commission, and one, Cameron LNG (formerly Hackberry), has received preliminary approval. Two more proposals for the offshore Gulf of Mexico have been filed with the U.S. Coast Guard.

The increase in proposed capacity between 2002 and 2003 includes both additional terminals and increases in capacity for many of those previously proposed. Proposed projects active during the summer of 2002 were primarily for terminals with a capacity of 1 billion cubic feet per day or less, whereas 9 of the current proposals are for terminals with a capacity of 1 to 2 billion cubic feet per day. If all the U.S. LNG facilities currently being proposed were completed, they would add more than 15 trillion cubic feet to annual U.S. import capacity. In addition, two proposed terminals in Mexico to serve Southern Mexican markets would have the indirect effect of reducing U.S. natural gas exports to Mexico.

Global developments are contributing to the domestic emphasis on LNG in the United States, as new liquefaction facilities proliferate around the world and potential supply sources expand. Until 1995, almost all U.S. LNG imports were from Algeria. More recently, shipments have also been received from Nigeria, the United Arab Emirates, Oman, Qatar, Malaysia, Australia, and Trinidad and Tobago. Additional sources of supply exist throughout the world where liquefaction facilities are either being developed or are in the planning stages.

Current worldwide liquefaction capacity and LNG consumption are roughly equivalent, at slightly over 6 trillion cubic feet per year, indicating that supply constraints are contributing to the current underutilization of U.S. regasification capacity. The equivalency of capacity and consumption is changing, however, with an additional annual capacity of 2 trillion cubic feet under construction and scheduled to come on line by 2006 and an additional 8.5 trillion cubic feet of capacity planned to come on line by 2011. Trinidad and Tobago, with current annual capacity of approximately 300 billion cubic feet, has now surpassed Algeria as the primary source of supply for U.S. markets. With an additional 157 billion cubic feet scheduled to come on line by 2006 and 570 billion cubic feet under consideration for development by 2011,

Figure 42. Existing U.S. LNG Terminals and New Terminals Planned in North America



Source: Energy Information Administration.

Trinidad and Tobago (located in relative proximity to the U.S.) is an important player in the future growth of the U.S. LNG market.

As the global market evolves, LNG is becoming an increasingly important energy source for many countries. A number of European and Asian nations already rely heavily on LNG. Japan, in particular, depends on LNG to meet its power generation needs, and the United States has been exporting LNG to Japan for more than 30 years from a liquefaction plant in Kenai, Alaska. As the world market for LNG continues to expand, natural gas is expected to become more of a global commodity, and the world natural gas market is expected increasingly to affect the U.S. market.

An important aspect of globalization is expansion of the LNG spot market. Internationally, most LNG currently is traded under long-term contracts. In recent years, however, the short-term market has played a more significant role, especially in the United States. Most of the LNG imported at the Everett terminal in Massachusetts remains under long-term contract at relatively stable quantities, but short-term deliveries at Lake Charles, Louisiana, have risen and fallen dramatically over the past few years, primarily in response to domestic natural gas prices.

Recent developments in Japan and South Korea illustrate the potential impact of global developments on the U.S. LNG market. In Japan, the forced closing of more than a dozen nuclear reactors in 2001 and 2002 because of reporting discrepancies led to greater reliance on fossil fuels for electricity generation. The result was a significant increase in Japan's demand for LNG, so that the majority of world spot cargoes were delivered to the Japanese market. Japan's increased reliance on LNG probably contributed to the reduction in short-term deliveries of LNG to the United States during the winter of 2001-2002, although low natural gas prices also played a role. In South Korea, an unusually cold winter in 2002-2003 led to the diversion of many spot cargoes to that country to meet unusually high demand for heating. The increase in shipments to South Korea may in part explain the low level of U.S. LNG imports during the winter of 2002-2003, when natural gas spot prices were spiking. These examples suggest that an assessment of future U.S. LNG consumption patterns cannot be based solely on the economics of the U.S. natural gas market.

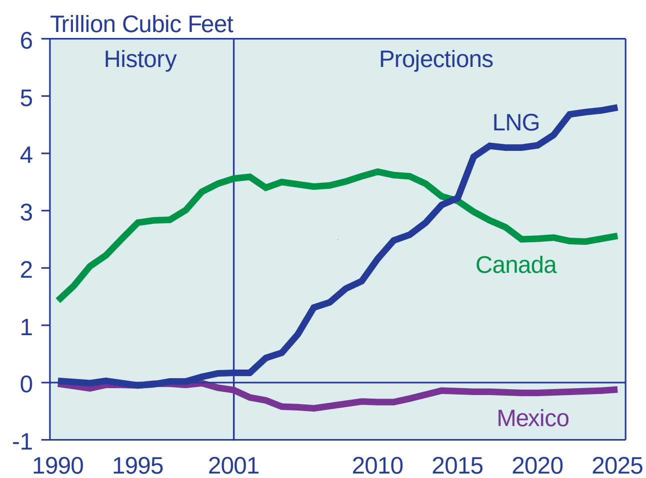
Canada

Canada is expected to continue producing more natural gas than it consumes; however, the amount of excess production available for export is expected to decrease. Like the United States, Canada has a growing need for natural gas for domestic use, while its supply basins are maturing, causing the pace of production increases to slow. In the *IEO2004* reference case, Canada's production is projected to grow at an average annual rate of 0.5 percent, while its consumption grows by 2.2 percent annually. In 2001, natural gas production in Canada exceeded consumption by 3.7 trillion cubic feet. In 2025 its excess production is projected to be 30 percent less, at 2.6 trillion cubic feet, most of which is expected to be exported to the United States.

Until recently Canada was expected to remain the primary source of natural gas imports for the United States through 2025, but it is currently projected that net U.S. imports of LNG will exceed its net imports from Canada by 2015 (Figure 43). The primary reason for the change is a significant downward reassessment by the Canadian National Energy Board (NEB) of expected natural gas production in Canada. In 1999, the NEB estimated that Canada's total production would be in a range of 8.1 to 9.0 trillion cubic feet in 2015 and 7.7 to 9.9 trillion cubic feet in 2025. In contrast, its 2003 estimates are 5.9 to 7.1 trillion cubic feet in 2015 and 4.3 to 6.1 trillion cubic feet in 2025.

Additional reasons for the downward reassessment of projected natural gas exports from Canada are declining natural gas production in the province of Alberta, which accounts for more than 75 percent of Canada's natural gas production, and increasing use of natural gas for oil sands production. In its most recent annual reserve report, the Alberta Energy and Utilities Board expects gas production in the province to decline at an average rate of 2 percent per year from 2003 to 2012, while its oil sands production could triple. Because natural gas is one of the fuels used in producing oil sands, such a dramatic increase could divert significant amounts of gas

Figure 43. Net U.S. Imports of Natural Gas, 1970-2025



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table A13.

from the U.S. import market. Other factors that could contribute to a decline in Canadian gas exports include higher projections for domestic natural gas demand in Canada and recent disappointments in Canadian drilling results, including smaller discoveries with lower initial production rates and faster decline rates.

Some major gas finds in recent years had contributed to the belief that Canada would continue to supply both its own needs and the bulk of U.S. import needs, but the discoveries are proving to be much less prolific than initially expected. One such find was the Ladyfern field in northeastern British Columbia. Production from the Ladyfern field, heralded as Canada's largest find in 15 years, peaked at 700 million cubic feet per day in 2002 and is declining rapidly. Current production is about 300 million cubic feet per day, and many expect the field to be depleted by the end of 2004. Another recent disappointment was the Scotian Shelf Deep Panuke field. In February 2003, EnCana (Canada's second largest oil company), initially highly optimistic about the field, requested that the regulatory approval process for developing it be placed on hold while it reassesses the economics of development.

The decline in Canada's exports of natural gas to the United States is expected to be mitigated by the construction of a pipeline that would bring MacKenzie Delta gas into Alberta. The gas would then be available both to serve Canada's internal needs and to provide exports to U.S. markets. Initial flows from the pipeline are expected in 2009, with annual throughput reaching approximately 675 billion cubic feet in 2012 and remaining at that level through the end of the forecast period.

Mexico

In Mexico, natural gas consumption is expected to far outstrip production over the forecast period. In the *IEO2004* reference case, Mexico's demand for natural gas is projected to grow at an average annual rate of 3.9 percent from 2001 to 2025, while production grows by 2.0 percent per year. The projected growth in demand is primarily to fuel natural gas combined-cycle electricity generation, but as infrastructure to serve residential and commercial users continues to grow, requirements for natural gas in all sectors is growing. Mexico thus faces an increasing dependence on imports, which is projected to grow from 7 percent in 2001 to 40 percent in 2025. This would leave Mexico in a precarious position, given that its only current source of imports is the United States, which is a net importer itself. Mexico is striving to remedy the situation in two ways, by developing LNG import facilities and by attracting foreign capital to help develop its own resources. The administration of Mexico's President Vincente Fox strongly supports both avenues of development.

LNG facilities have been proposed at Altamira on Mexico's Gulf coast and at Lazaro Cardenas on its Pacific coast. Five facilities have been proposed in Baja California, Mexico, to serve both Mexican and U.S. markets. As of late November 2003, the Mexican Energy Regulatory Commission had granted some of the required permits for the Altamira terminal and for three Baja California terminals—those proposed by Marathon Oil, Sempra Energy, and Shell. Mexico is not immune to local opposition, however, and concerns have been raised by citizens' groups in Baja California about health and safety issues that could slow (or even stop) progress on some projects.

Pemex, Mexico's state-owned oil and gas company, has to date concentrated its exploration and development efforts on oil, finding it to be more profitable than gas. As a result, a vast potential still exists for development of its indigenous gas resources. According to the Mexican government, only 10 percent of its onshore resources have been explored, 4 percent of offshore regions considered to have good potential have been explored, and no exploration has occurred in the deep offshore. Pemex wants to place a stronger emphasis on gas, but it lacks funds to finance the development.

Approximately 2 years ago, the government began a campaign to attract foreign investment through Multiple Service Contracts (MSCs), under which a contractor would handle multiple phases of development, such as arranging financing for a project to develop and produce reserves in a given block, produce the gas, build any needed pipeline infrastructure to deliver the gas, and deliver the gas to Pemex. MSCs were shunned by potential bidders when they were first proposed because of terms deemed unfavorable to investors: the Mexican constitution prohibits foreign ownership of any of its oil and gas assets and also stipulates that payment for help in developing its oil and gas resources must be for services rendered and cannot be linked in any way to the level of production. Accordingly, foreign companies would be prohibited from booking reserves, and their profit margins would be limited, even when gas prices rose, making the contracts economically unattractive. The situation is further complicated by the fact that elements of the Mexican government are declaring that the MSCs, even with all their stipulations, violate the Mexican constitution and are thus illegal and subject to being overturned.

After numerous revisions to the terms of the contracts, attempts to attract foreign investment through MSCs have finally begun to show some progress. Out of seven MSC tenders for help in developing natural gas reserves in the Burgos Basin in northwestern Mexico, four contracts were awarded. The contracts, hopefully, will lead to an additional 400 million feet per day of production, still far short of the 1,000 million cubic feet per day that Pemex had hoped the contracts would yield by 2006. The hoped-for 1,000 million cubic feet per day would have satisfied 15 percent of the domestic demand projected by the Mexican government and lessened reliance on imports, which have averaged around 700 million feet per day for most of 2003. Some large oil companies, including ExxonMobil and Total, purchased tender documents but later decided not to proceed; most international oil companies showed no interest at all.

Pemex has announced that it will accept feedback from bidders on how to make the contracts more acceptable while still complying with Mexican constitutional law before re-offering the blocks that were not bid on. It is anticipated that this will happen in early 2004. In the middle of 2004, Pemex plans to offer a second round of tenders to develop resources along its Gulf coast and in the south near the Bay of Campeche. It is hoped that some combination of production developed under the MSCs and LNG imports will allow Mexico to become more self-sufficient and less dependent on the United States for its gas requirements in the future.

Western Europe

Natural gas is expected to be the fastest growing fuel source in Western Europe, with demand projected to grow at an average annual rate of 2.0 percent, from 14.8 trillion cubic feet in 2001 to 23.7 trillion cubic feet in 2025. Western Europe currently holds less than 4 percent of the world's proved natural gas reserves, and its production is projected to decline from 10.2 trillion cubic feet in 2001 to 9.8 trillion cubic feet in 2025 (see Table 11). As a result, the region is expected to become increasingly dependent on imports, especially toward the end of the forecast period, when growth in natural gas consumption is expected to accelerate. In 2001, 31 percent of Western Europe's natural gas supply was imported from outside the region; *IEO2004* projects that in 2025 Western Europe will need to import 59 percent.

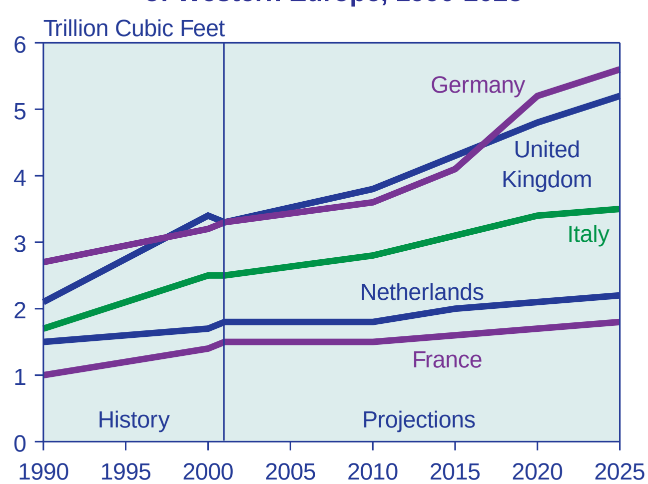
Western Europe's largest consumers, in order of amount consumed in 2002, are the United Kingdom, Germany, Italy, the Netherlands, and France (Figure 44). Between 2015 and 2020, Germany is expected to replace the United Kingdom as Western Europe's largest natural gas consumer and remain there through the rest of the forecast period, in part due to its commitment to phase out nuclear power over the next 20 years. In 2025, Germany is projected to consume 5.6 trillion cubic feet of natural gas and the United Kingdom 5.2 trillion cubic feet.

The United Kingdom, with an estimated 26.0 trillion cubic feet of natural gas reserves, is at present both Western Europe's largest producer and largest consumer of natural gas. Until the mid-1990s, it was a net importer of gas, shifting to a net exporter after 1997 when its production began to increase as deregulation and privatization of the U.K. gas industry progressed. A major milestone in the process was the passage of the 1995 Gas Act, which split up British Gas, at the time the monopoly supplier to the interruptible market, and brought in competition. The privatization of the gas industry led to increased gas supply at reduced prices, which lowered the United Kingdom's reliance on coal for electricity generation. The U.K. natural gas market has continued to grow, as has its share of electricity generation. The natural gas share of utility fuels, which was 1 percent in 1988 [*8*], is projected to increase to almost 50 percent by 2010.

Natural gas consumption in both the Netherlands and France is projected to grow modestly over the forecast period, to 2.2 and 1.8 trillion cubic feet, respectively, in 2025. France is expected to remain the smallest of Western Europe's top five consumers, in part because the French natural gas market is controlled by the state gas company, Gaz de France. The French government was slow to liberalize its natural gas market to conform to the mandates of the European Gas Directive, which did not become national law until almost 3 years after the EU deadline. The French Electricity Regulation Commission contends that the market limits competition because of an overabundance of long-term contracts with foreign groups. Gaz de France currently dominates supply, but this will change when the Commission takes regulatory control of the natural gas market as scheduled in 2004. At that time it intends to introduce more flexibility into contractual terms and foster competition. In the meantime, growth in natural gas consumption is slow and is expected to show little increase until after 2010.

In the other Western European countries, natural gas consumption is projected to grow at a combined average

Figure 44. Natural Gas Consumption in Countries of Western Europe, 1990-2025



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

rate of 3.3 percent per year. Some of the most rapid growth in natural gas consumption is occurring in Spain and Portugal, where gas markets have only recently begun to flourish. Between 2001 and 2002, Portugal saw a 21.0-percent increase in consumption and Spain saw a 14.4-percent increase. In 1998, Portugal's gas consumption increased from less than 10 billion cubic feet to 28 billion cubic feet; in 1999, consumption again increased dramatically, to 80 billion cubic feet.

Although virtually all of Portugal's natural gas comes by pipeline from Algeria, Portugal began importing LNG in 1998 and in 1999 entered into a contract to purchase LNG from Nigeria for 20 years beginning in 2002. The LNG was regasified initially in Spain and piped into Portugal until Portugal's own regasification terminal at Sines became operational in October 2003. The Sines terminal, operated by Gas de Portugal, has an annual capacity of 146 billion cubic feet, more than twice Portugal's 61 billion cubic feet of consumption in 2002. Almost all of the natural gas consumption in Portugal is for electricity generation.

Spain is considered one of the world's most rapidly growing natural gas markets. Consumption over the past 10 years has more than tripled. The country is in the process of phasing out its older nuclear and coal-fired power plants in favor of gas. Almost entirely dependent on imports to satisfy demand, Spain currently has three LNG receiving terminals operated by state-owned Enagas—in Barcelona, Huelva, and Cartagena. The terminals became operational in 1969, 1988, and 1999, respectively, and all are being expanded. A fourth terminal in the port of Bilboa in the northwestern Basque region, operated by a consortium of BP, Iberdrola, Repsol YPF, and EVE, came on line in August 2003. There are also two new terminals currently under construction at El Ferrol and Sagunto, both scheduled to come on line in 2006-2007. Both will be operated by consortia. In 2002, Spain received 59 percent of its gas imports as LNG and the remainder as pipeline imports from Norway and Algeria.

The major producing countries in Western Europe are, in order of amount produced in 2002, the United Kingdom, Norway, and the Netherlands. In 2002, they together produced 8.0 trillion cubic feet of gas and consumed 4.9 trillion cubic feet, exporting all but a small amount of the remainder to other Western European countries. These three countries contain most of Western Europe's indigenous natural gas resources. Most of the reserves in the United Kingdom and the Netherlands are in mature gas fields considered to be in decline, and the likelihood of major new finds is small.

Norway also has maturing gas fields, but it has extensive offshore reserves. Norway's proved reserves at the end of 2002 showed more than a 75-percent increase over proved reserves at the end of 2001, primarily because of the discovery of the offshore Ormen Lange field, estimated to contain 13.3 trillion cubic feet of recoverable reserves. Production from Ormen Lange is expected to begin in 2007, with most of the gas destined for the United Kingdom. Norway itself consumes only about 150 billion cubic feet of natural gas per year and exports the rest.

Western Europe's dependence on natural gas imports from other regions has been growing for some time. The Western European natural gas market was relatively self-contained until the early 1970s, when consumption first began to exceed production. The gap was filled by LNG imports that started arriving from Algeria and Libya and pipeline imports that started flowing from the Soviet Union. Over the years, additional pipeline capacity from the Soviet Union and north Africa was added. Currently, the primary sources for imports of natural gas to all of Western Europe are pipeline imports from Russia and Algeria and LNG from numerous sources, including Algeria. In 2002, the region imported more than 35 percent of its supplies. Russia provided 43 percent of the imported gas, Algeria provided 16 percent as pipeline imports and an additional 31 percent as LNG, and the remaining 10 percent was imported as LNG from Algeria, Nigeria, Qatar, Oman, Libya, Trinidad and Tobago, the United Arab Emirates, Australia, and Brunei.

Germany, Italy, and France are Western Europe's biggest natural gas importers. Germany received 38 percent of its supplies from Russia, with the remainder coming from within the region. Italy received 30 percent of its supplies by pipeline from Russia, 32 percent by pipeline from Algeria, and 9 percent as LNG from Algeria and Nigeria. France, Spain, and Italy are Western Europe's biggest importers of LNG. Together, the three countries in 2002 imported 23 percent of their total consumption as LNG and 45 percent as pipeline imports from Russia and Algeria.

The *IEO2004* forecast expects Western Europe's LNG consumption to grow strongly over the projection period. Western Europe currently has 10 operating LNG import facilities—4 in Spain, 2 in France, 1 in Belgium, 1 in Greece, 1 in Italy, and 1 in Portugal—with a combined capacity of about 2,000 billion cubic feet per year. Considerable infrastructure development is planned to increase LNG import capacity (Figure 45). Expansion is underway at 3 of Spain's 4 facilities, and 2 new ones are under construction, adding 526 billion cubic feet of annual capacity by 2007. In the United Kingdom, plans are in the works for 161 billion cubic feet of annual capacity. In addition to projects already underway, an additional 2,100 billion cubic feet of capacity has been proposed for completion before 2010. The added capacity proposed is for Belgium, France, Italy, the Netherlands, and the United Kingdom.

In addition to its plans to import LNG, the United Kingdom is in the process of developing other sources of supply to meet the projected future needs. Centrica (formerly British Gas), a major energy supplier, has negotiated import agreements scheduled to start in 2005 with Statoil of Norway and Gasunie of the Netherlands. Proposals for new import pipelines are also being considered to transport offshore gas (likely to include gas from Norway's Ormen Lange field) to the United Kingdom; and plans have been announced to add compression by 2005 that will almost triple the capacity of the Interconnector at Bacton, one of two major pipelines used to bring gas into the United Kingdom.

Norway is entering the LNG market as an exporter. Gas from the Snohvit and other fields in the Barents Sea will be processed in what will be the largest sub-sea LNG project in the world for the international Snohvit Group, a consortium of oil companies that includes the Norwegian Statoil ASA, Norsk Hydro, and French TotalFinaElf S.A. The plant, now under construction on Melkoye Island, will have a capacity of 200 billion cubic feet per year. It is expected to go into production by 2006, with exports targeting markets in Spain, France, and the United States. In November 2002, Statoil purchased capacity rights at the Cove Point, Maryland, import terminal, gaining 20-year access to one-third of the terminal's capacity. This will be the first time that Western European LNG exports have targeted the United States.

Russia is the largest supplier of natural gas imports to Western Europe, and the second largest supplier is North Africa (primarily Algeria), delivering supplies by pipeline to Italy, Spain, and Portugal and by LNG tanker to France, Spain, Italy, Belgium, Greece, and Portugal. Algeria is increasing its exploration efforts and encouraging foreign investment in the further development of its natural gas transmission and export activities. Egypt is also expected to become a supplier of gas to Western Europe. A two-train LNG liquefaction facility is currently under construction at Idku, with an expected completion date of 2005. The first train has already been committed to Gaz de France, and the second train has been committed to Centrica for delivery to Italian and U.S. markets.

Industrialized Asia

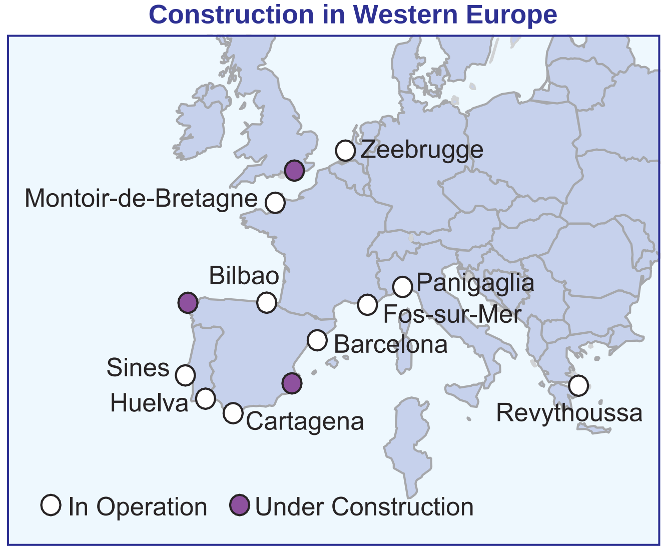
In the three countries of industrialized Asia—Japan, Australia, and New Zealand—annual natural gas consumption grew by 50 percent over the 1991-2001 period, from 2.6 trillion cubic feet to 3.9 trillion cubic feet. In the *IEO2004* reference case, their combined demand is projected to grow by 1.8 percent per year on average, to 6.0 trillion cubic feet in 2025. Australia and New Zealand account for about one-third of the projected increase. Australia began to exploit its sizable natural gas resources relatively recently, and in both Australia and New Zealand increased natural gas consumption is projected to accompany strong economic growth over the forecast period.

Japan

Japan's natural gas consumption is projected to grow from 2.8 trillion cubic feet in 2001 to 4.2 trillion cubic feet in 2025, at an average rate of 1.6 percent per year—about the same rate as Japan's projected economic growth rate over the period. As the world's largest LNG importer, Japan plays a key role in the Asia-Pacific natural gas trade. From 1990 to 2001, Japanese gas consumption grew 47 percent. Japan's proved natural gas reserves are estimated at 1.4 trillion cubic feet [***9***], and about 97 percent of natural gas demand in Japan is met by LNG imports. Most of Japan's 2,567 billion cubic feet of imports in 2002 was purchased under long-term contracts and around 1 percent on the spot market.

In 2003, Japanese companies continued to pursue new contracts for natural gas imports to replace expiring contracts and to increase supply. Japan had 23 LNG importing terminals on line in 2003 [***10***]. Its three major gas companies succeeded in signing a joint agreement with Malaysia's MLNG Tiga project in 2002, to begin delivery in 2004. The agreement gives the importer a level of flexibility uncommon in LNG contracts. Tokyo Gas and Toho Gas signed a contract on more traditional terms in October 2001 for LNG purchases from Australia's North West Shelf LNG project, also to begin in 2004. Shell's Sakhalin-2 project in Russia also signed contracts early in 2003 with both Tokyo Electric Power (TEPCO) and Tokyo Gas, to begin delivery in 2007 [***11***]. The expiration of several long-term contracts between Japan and Indonesia in the next few years has generated competition from suppliers. While price issues are important in such contracts, the Japanese companies are also focusing on

Figure 45. LNG Terminals in Operation and Under Construction in Western Europe



Source: Energy Information Administration.

reliability of deliveries in arrangements that will last for as long as 20 years.

Japan's national gas grid currently serves 25 million residential consumers. Japan has 1,400 miles of transmission line, 17,600 miles of medium-distance pipeline and 127,000 miles of low-pressure pipeline [*12*]. The Japanese government has slowly begun to deregulate the natural gas industry, leading to the increased domestic competition. Gas prices are linked to the Japan Customs Cleared Crude price [*13*]. In 2001, 72 percent of natural gas utilization was for power generation [*14*]. City gas consumption has increased by more than 70 percent in the past decade due to a 25-percent increase in natural gas customers and also to a large rise in consumption by industry (Figure 46).

Australia/New Zealand

Australia and New Zealand consumed a combined 1.1 trillion cubic feet of natural gas in 2001, and their consumption is projected to increase at an average annual rate of increase of 2.2 percent, to 1.8 trillion cubic feet by 2025. Relative to neighboring Australia, New Zealand has modest natural gas resources: its proved natural gas reserves were estimated at 1.3 trillion cubic feet in 2004 [*15*]. New Zealand's largest natural gas field, the Maui field, supplies 80 percent of the country's gas needs, but it has lost production capacity in recent years and is likely be exhausted by 2007. Several companies have proposed developing LNG import facilities rather than expend additional resources on exploration, which has returned poor results in recent years. Two new fields, Pohokura and Kapuni, have failed to yield the same low-cost production as the Maui field. New Zealand's largest power companies are partnering with Shell on the construction of regasification infrastructure.

Australia is the third largest LNG exporter in the Asia-Pacific region, after Indonesia and Malaysia. The Australian government has worked to streamline project approval and certification to allow the country's producers to compete in what has been a buyer's LNG market in Asia until recently. Australia's North West Shelf venture owns the country's only liquefaction plant, the Withnell Bay LNG facility, which has three trains and a total capacity of 7.5 million metric tons per year. A fourth train is scheduled to come on line in mid-2004, and a fifth train is under consideration.

The Darwin liquefaction plant, currently under construction, is scheduled for completion in 2004. All 3.6 million metric tons of LNG from the Darwin project has been contracted to Tokyo Electric/Tokyo Gas. Two additional projects have been proposed. Greater Sunrise, located on the Timor Sea, would have a capacity of 5.3 million metric tons per year. The project could be completed by 2009. The Gorgon LNG project, proposed by ChevronTexaco, ExxonMobil, and Shell, would have a capacity of 10.0 million metric tons per year and could be on line in 2008. The Gorgon project has signed a memorandum of understanding with China for 5 million metric tons per year and another to supply 4 million metric tons per year to a potential terminal on the U.S. West Coast [*16*].

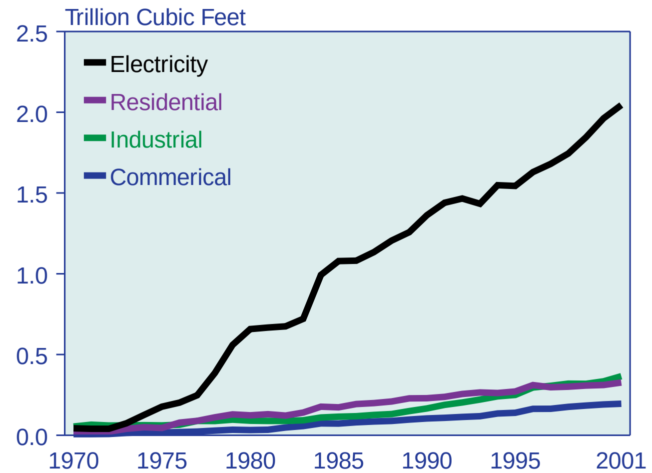
Eastern Europe and the Former Soviet Union

The EE/FSU region holds more than 35 percent of the world's natural gas reserves and accounts for 28 percent of global production [*17*]. In 2002, Russia produced 78 percent of the gas brought to market in the region and 22 percent of the gas marketed globally, surpassing production in the United States [*18*]. In the *IEO2004* reference case, natural gas consumption in the EE/FSU region is projected to reach 39.0 trillion cubic feet in 2025, growing at an average annual rate of 2.1 percent over the forecast period. Consumption is expected to grow by 3.6 percent per year in Eastern Europe and 1.9 percent per year in the FSU. Overall production in the FSU is projected to grow at a rate of 2.1 percent per year, which would assure its status as a major exporter through 2025 (Figure 47).

Changes in the pattern of natural gas use between 1991 and 2001 varied among the EE/FSU nations. In Turkmenistan, Uzbekistan, Hungary, and the Czech Republic there were marked increases in gas use, and in Georgia, Albania, and Azerbaijan there were significant decreases. Since the fall of the Soviet Union in the early 1990s, both economic growth and natural gas consumption have rebounded faster in Eastern European than in the FSU.

In 2001 the FSU countries produced 4.9 trillion cubic feet more gas than they consumed, and in 2025 they are

Figure 46. Natural Gas Consumption in Japan by Sector, 1970-2001



Sources: International Energy Agency, *Energy Balances of OECD Countries* (Paris, France, various issues); and Energy Information Administration, International Statistics Database.

projected to produce 11.7 trillion cubic feet more than they consume, more than double the 2001 amount. Infrastructure expansion will be required for the FSU to be able to market additional gas, and some expansion is already underway.

Recent developments in the EE/FSU natural gas market include completion of major pipeline projects, the signing of new international trade agreements, and progress on several infrastructure expansion proposals to facilitate international trade. One notable project is a pipeline linking Turkmenistan to Afghanistan and Pakistan. On February 27, 2004, President Niyazov instructed the Turkmen Oil and Gas Ministry to determine the extent of its actual reserves as part of its planning for the $3.5 billion Trans-Afghanistan pipeline. Originally proposed in 1997, the project was put on hold because of tensions between Afghanistan and Pakistan; however, since the fall of the Taliban regime in Afghanistan it has drawn strong international (including U.S.) support. Turkmenistan is also pursuing long-term arrangements to provide gas to both Russia and Ukraine and has already signed a 25-year deal to provide gas to Russia.

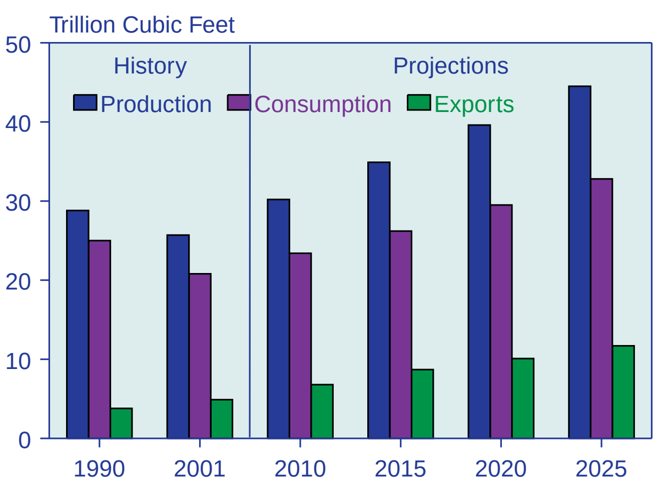
In 2002, natural gas production increased in Russia, Georgia, Uzbekistan, Poland, and Kazakhstan and fell in most of the other EE/FSU countries. The main exporters of gas were Russia, Kazakhstan, Turkmenistan, and Uzbekistan. Belarus, the Czech Republic, Slovakia, and Hungary were among the region's largest importers in 2002. Kazakhstan, a net importer, also exported about 70 billion cubic feet of gas to other countries in the region. Overall gas production in the EE/FSU has been increasing over the past few years, but consumption still remains well below the levels of the early 1990s.

Russia is a preeminent force in global natural gas trade. In 2002, it exported 4.5 trillion cubic feet of gas to other European countries (Figure 48) and to Turkey, accounting for 29 percent of global pipeline trade [***19***]. The only other significant regional participant in the pipeline trade was Turkmenistan, with a 1.1-percent market share consisting of deliveries to Iran. Russia's total exports were flat from 2001 to 2002, with slightly lower exports to Western Europe and slightly higher exports to Eastern Europe. In 2002, Western Europe received 64 percent of Russia's exports.

Russia is exploring options to export natural gas to China and South Korea. Gazprom, Rusiya Petroleum, South Korea's state-owned Korea Gas Corporation (KOGAS), and the Chinese National Petroleum Company (CNPC) have started negotiations on the construction of a pipeline that would connect Russia's Kovykta field to South Korea and provinces in Northeast China. The pipeline, with a capacity of 706 billion cubic feet per year, would deliver about two-thirds of its gas annually to China and the remainder to South Korea. It is expected to come on line as early as 2008.

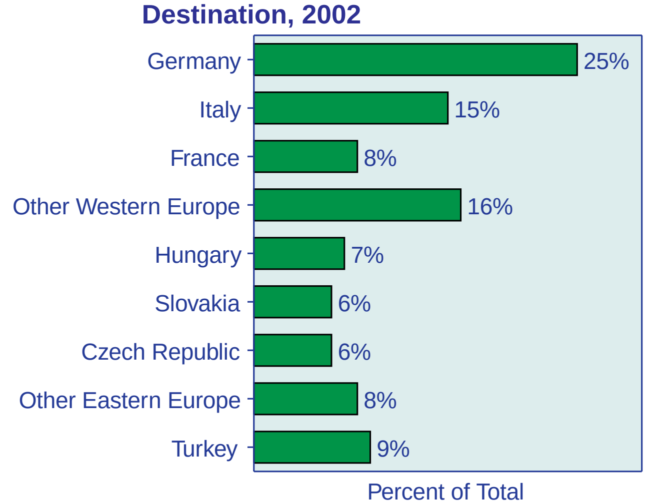
Europe is Russia's primary export market, but Turkey has long been seen as a potential outlet for Russian gas. Currently Russia's fastest growing export market, Turkey jumped ahead of France to become Russia's third largest foreign customer in 2002. Exports to Turkey are expected to continue to grow with the opening of the Blue Stream pipeline in October 2002. Shortly after it began commercial shipments, however, Turkey ceased accepting Russian gas through the Blue Stream, claiming that the price was too high and that by the terms of its contract it could cease acceptance for 6 months

Figure 47. Natural Gas Production, Consumption, and Exports in the FSU Region, 1990-2025



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

Figure 48. Russian Natural Gas Exports by Destination, 2002



Source: Cedigaz.

without penalty. A new price agreement was reached several months later, and Russia expects to send record supplies to Turkey in 2004, in part because a recent boiler explosion at Algeria's Skidka facility is expected to have a severe impact on exports to Turkey in the near term.

Russia is anticipating that Turkey will become a future transit route to Europe, bypassing Ukraine, Romania, and Bulgaria. All Russian supplies entering Turkey transited those three countries before the Blue Stream was opened, and Russia has long sought alternate routes. The Blue Stream is just one of Russia's attempts to bypass Ukraine; the recently completed second line of the Yamal-Europe pipeline transports gas from Russia's Yamal Peninsula to Germany via Belarus and Poland. The first Yamal-Europe line transits Belarus and Ukraine.

Relations between Russia and Ukraine regarding the transport of Russian gas have been under strain. Tensions arose from Ukraine's failure to keep current in its payments for gas imported from Russia and from Russia's accusation that Ukraine was siphoning gas during transit. Relations between the two countries are improving, however. On August 29, 2003, Russia and Ukraine entered into an agreement under which Russia will ship 4.5 trillion cubic feet to and through Ukraine in 2004, 3.9 trillion cubic feet of which will be destined for export to various European countries. Part of the transit fee will be paid in kind and the rest in cash. As part of the same agreement, Gazprom guaranteed the transport of 1.3 trillion cubic feet of gas, primarily from Turkmenistan, through Russia to Ukraine. Additional stipulations will allow Ukraine to export limited amounts of its own gas under Gazprom's export contracts and to re-export limited amounts of the gas it buys from Gazprom.

Russia is currently Poland's major source of natural gas. In addition to attempting to diversify import sources, the Polish government continues to talk of increasing its own production to assure stability of supply at reasonable prices. In 2002, a long-term natural gas supply agreement between Norway's Statoil and Poland was reached, with Statoil agreeing to begin sending supplies in 2008 through a dedicated pipeline to be constructed from the North Sea to Poland. Plans were aborted in late 2003 at the urging of Polish Prime Minister Leszek Miller because of lower estimates of Poland's gas requirements and the availability of cheaper Russian gas. Shortly thereafter, in the wake of Gazprom's curtailment of supplies because of transit problems in Belarus, Poland entered into a memorandum of understanding with Statoil to increase supplies and diversify import options.

There are still issues to be resolved before EE/FSU natural gas markets are fully developed and open, but the state of the market today is far superior to that of the early to mid-1990s, when gas markets in most EE/FSU countries were almost completely controlled by national governments, and efforts at privatization and foreign involvement were just beginning to develop. The climate for foreign investment in the EE/FSU, particularly Russia, continues to improve, fostered by the region's vast energy resources and recent continued economic growth.

Russia, in particular, is attracting record investment from major Western companies. A good example is Sakhalin Island, where five oil and gas projects are separately operated by unique international consortia [***20***]. Sakhalin I and II are expected to bring oil and gas supplies on line in the next 5 years. The Sakhalin I project is expected to begin piping gas to Japan in 2008. Sakhalin II, which involves the development of Russia's first natural gas liquefaction facility, is expected to begin supplying exports to Japan (and possibly the United States) in 2007. As another example, in June 2003 Germany's Wintershall joined with Gazprom in a joint venture for the production of natural gas from Russia's Urengoi field, with initial development to begin in 2004 and full production in 2008.

Central and South America

Although the natural gas industry in Central and South America is still at an early stage of development, expanding exploration and infrastructure activities in several countries have yielded promising results. Natural gas markets in the region constituted 3.9 percent of world natural gas consumption in 2001. At the beginning of 2004, Central and South America held 4.1 percent of the world's proved natural gas reserves, about 250 trillion cubic feet [***21***]. Natural gas consumption in the region increased from 2.0 trillion cubic feet in 1990 to 3.5 trillion cubic feet in 2001 and is projected to grow at an average annual rate of 3.8 percent per year to 8.5 trillion cubic feet in 2025.

The region's largest natural gas reserves are in Venezuela (148 trillion cubic feet). Trinidad and Tobago, Bolivia, and Argentina also hold reserves of more than 20 trillion cubic feet, and Brazil and Peru have reserves of about 8 trillion cubic feet. Currently, production of natural gas in Central and South America is sufficient to meet regional demand, but only Trinidad and Tobago exports natural gas to other regions, including 187 billion cubic feet of LNG marketed to the United States in 2002 [***22***].

Brazil

From 1991 to 2001, as a result of rapid economic growth and favorable government energy policies, Brazil's natural gas consumption rose from 119 billion cubic feet to 339 billion cubic feet, accounting for 12 percent of regional consumption in 2001 [***23***]. In 2002, Argentina and Bolivia exported 16.9 billion cubic feet and 139.4 billion cubic feet of natural gas to Brazil, respectively. Brazil's own reserves stood at 8.5 trillion cubic feet at the beginning of 2004 [*24*]. Brazil imports 44 percent of its natural gas. The state-controlled energy company, Petrobras, dominates upstream production in Brazil, while distribution falls to the states.

Brazil's largest natural gas reserves are off its south central coast. The recent discovery of an additional 14.8 trillion cubic feet in the Santos basin nearly tripled Brazil's natural gas reserves, moving Petrobras closer to its goal of Brazilian energy self-sufficiency [*25*]. The discovery of unanticipated reserves is particularly important with regard to the Bolivia-Brazil Gasbol pipeline, which was built as part of a 20-year take-or-pay agreement signed in June 1999 [*26*]. Brazil's 1999 plan to expand gas-fired electricity generation capacity was curtailed in 2002, however, as a result of federal and state budget woes stemming from volatility in currency and debt markets. Of the 16 gas-fired electricity plants envisioned in 1999, only 10 are likely to be constructed in the foreseeable future [*27*]. In light of lower investment in electricity generation capacity and recent domestic natural gas discoveries, Brazil is attempting to reduce its import obligations with Bolivia.

The push for an increase in gas infrastructure by the previous presidential administration also aimed to reduce Brazil's dependence on hydropower, after a drought in 2001 led to electricity rationing and blackouts and contributed to Brazil's economic downturn. In 2003, however, favorable weather conditions created an energy surplus, and the new administration has announced an initiative to meet the nation's growing electricity needs largely through expansions of hydroelectric capacity. The Brazilian Basic Infrastructure and Industry Association has estimated that increases in generating capacity on the order of 5 gigawatts annually will be needed to prevent shortfalls after 2007 [*28*].

Other Central and South America

Argentina's natural gas sector continues to be affected by reduced consumer and investor confidence following a 2002 economic crisis that was set off by a 30-percent devaluation of the Argentine peso. The country's natural gas sector is entirely privately held, dominated by privatized former state enterprises now largely owned by major international players. Argentina has 23 trillion cubic feet of proved reserves [*29*]. In 2001, it produced 1,098 billion cubic feet of natural gas and exported 206 billion cubic feet to Chile, Brazil, and Uruguay [*30*]. In Argentina, unlike many other Latin American countries, natural gas has permeated beyond industrial and utility applications to commercial and residential use. One noteworthy example is that 11 percent of road transportation is fueled by compressed natural gas, constituting 5 percent of Argentina's natural gas usage [*31*].

Venezuela has proved natural gas reserves of 148 trillion cubic feet [*32*], and the USGS estimates that about 67 trillion cubic feet remains to be discovered [*33*]. Venezuela's reserves account for 58 percent of South America's total, but Venezuela lacks adequate infrastructure to take advantage of its natural gas abundance. Although Venezuela brought 960 billion cubic feet to market in 2000, because its reserves are mostly associated gas, another 159 billion cubic feet was flared or vented and 752 billion cubic feet was reinjected [*34*]. Venezuela's petroleum industry was troubled by political unrest in 2003, but its natural gas production contracted by only 3 percent in the first half of the year, when disruptions were at their worst [*35*]. The largest part of Venezuelan gas reserves is offshore, near its border with Trinidad and Tobago. In addition, a recent onshore discovery of 2.5 trillion cubic feet presents another opportunity for development [*36*]. At current consumption levels, Venezuela's proved reserves would satisfy 101 years of domestic demand [*37*]. Its transmission and distribution system serves to supply gas mainly to industrial consumers, and only the five largest metropolitan areas have notable distribution networks for residential consumption [*38*].

Petróleos de Venezuela (PDVSA), the state-run energy company, dominates the natural gas sector; however, Venezuela did begin opening the sector for foreign investment in 1999 and offered the first licenses to private participants for nonassociated gas exploration in 2001. The current administration of President Hugo Chavez hopes to increase gas production and generate export opportunities, but continued political unrest and general strikes by PDVSA employees have diminished the potential interest of investors.

Venezuela is considering exporting natural gas as LNG. PDVSA, Royal Dutch/Shell, and Mitsubishi signed a preliminary development agreement to begin a feasibility study for an LNG plant that would process natural gas off the Paria peninsula, but the venture is also weighed down by the political instability of the current regime. Trinidad and Tobago and Venezuela signed a memorandum of understanding regarding the utilization of the natural resources on their shared border. The agreement is the first of its kind in the Western Hemisphere. Venezuelan reserves are larger than the reserves of Trinidad and Tobago, which has a more developed infrastructure. Under the terms of the memorandum, British Petroleum Platforma Deltana will use Trinidad and Tobago's infrastructure to help transport Venezuelan reserves [*39*].

Trinidad and Tobago exported 151 billion cubic feet of LNG to the United States in 2002, 80 percent of its annual LNG production. Another 11 percent went to Puerto Rico and 9 percent to Spain. Trinidad and Tobago has a cost advantage over other LNG exporters targeting the

U.S. market because its proximity to the United States significantly reduces the cost of transporting LNG.

Bolivia is considering exporting LNG, but the gas would have to be piped to the coast through either Peru or Chile. Although building the pipeline through Chile makes more economic sense, a 117-year-old territorial feud between Bolivia and Chile makes the idea politically unpopular. The project, backed by Total, Repsol, BG, and Sempra, is now on hold following public protests and the resignation of President Gonzalo Sanchez de Lorzado [***40***].

There is also a proposal in Peru that would export gas from the Camisea field to markets along the U.S. and Mexican west coasts [***41***]. An export agreement has been reached between U.S.-based Hunt Oil, which is building the Peruvian liquefaction terminal, and Belgium's Tractabel, which hopes to build regasification facilities in western Mexico. The project faces opposition on environmental grounds, because the pipeline would run through sections of the Peruvian rain forest, and the liquefaction facility would be situated near a wildlife sanctuary. The Camisea consortium approached the U.S. Export-Import Bank for a loan, but the request was rejected because of the environmental sensitivity of the project; however, despite the abstention of its U.S. representative, the Inter-American Development Bank approved a loan for the project. The Andean Development Bank also granted a loan for the project.

Developing Asia

The *IEO2004* reference case projects continued rapid growth in natural gas consumption among the countries of developing Asia. Regional natural gas consumption between 2001 and 2025 is projected to increase by 3.5 percent on average per year, about twice as fast as the rate projected for the countries of the industrialized world (Figure 49). Underlying causes include countries' desire for fuel source diversification, particularly for electricity generation, and environmental concerns, particularly in large urban centers.

As the region's largest producers, Indonesia and Malaysia play an important role in natural gas markets; however, the pace is likely to be set by the region's fastest growing energy consumers, China and India. Both have continued their efforts to increase natural gas supplies and develop the infrastructure needed to bring gas to market. China and India together account for 57 percent of the expected regional increment in natural gas use, with projected average annual increases of 6.9 percent and 4.8 percent, respectively.

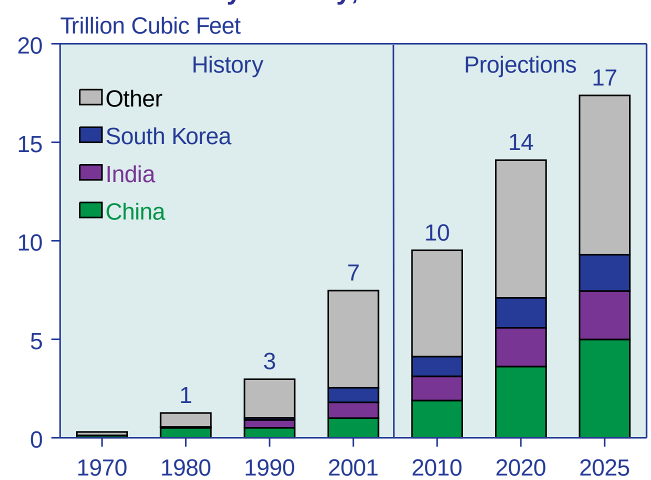
China

Although natural gas use accounted for only 3 percent of China's energy mix in 2001, the Chinese government has recently taken aggressive steps to develop natural gas production, transportation, and import capacity. The government aims to reduce Beijing's dependence on coal by bringing the city's natural gas infrastructure to full operational capacity by 2008 as part of a $12 billion program to clean up the city before it hosts the Olympic games in 2008. In addition, Shanghai province has stopped construction of coal-fired generation facilities in anticipation of inclusion in the nation's developing natural gas transportation system.

China's natural gas reserves were estimated at 53.3 trillion cubic feet in 2002. In 2001, it consumed 1.0 trillion cubic feet of natural gas. China's three gas producers are state-controlled companies, each of which focuses its operations in a different part of the country. Petrochina/ Chinese National Petroleum Corporation (CNPC), which concentrates in the north and west of the country, is China's largest producer [***42***]. Sinopec concentrates on southern basins and works with CNPC in some fields in Sichuan province. A large part of Sinopec's business includes refining operations that lack the profitability of the upstream work of the other national oil companies. China National Offshore Oil Corporation (CNOOC) concentrates on offshore production; it produced 128 billion cubic feet of natural gas in 2003 [***43***].

China's natural gas infrastructure is growing quickly. Given that natural gas can help provide electricity and meet environmental objectives, the Chinese government is encouraging the development of gas-fired electricity generation. The distribution system in Sichuan province already has 5,400 miles of pipeline serving industrial and residential customers. In September 2003, Petrochina started building a 454-mile pipeline with a capacity of 116 billion cubic feet per year, connecting

Figure 49. Natural Gas Consumption in Developing Asia by Country, 1970-2025



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/ iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

Zhongxian field in Sichuan to the Hubei province with the potential of an extension to the eastern coast [*44*]. In August 2003, CNOOC completed construction on a pipeline from the South China Sea to the east coast as part of a drive to increase access to offshore resources in the area.

Petrochina is building a 2,500-mile-long west-to-east pipeline from the Tarim basin in Xinjiang to Shanghai and Beijing with an annual capacity of 706 billion cubic feet. The pipeline connects gas fields in China's sparsely populated west to urban markets in the east. The eastern section of the pipeline, from the Ordos basin to Shanghai, came on line in October 2003, and the western portion is scheduled to come on line in October 2004.

China is also increasing its potential to import natural gas. Several pipelines from eastern Russian fields in Sakhalin or Irkutsk are being considered to deliver gas into Shenyang in northeastern China. The countries have already negotiated a connection from Russia's Kovytka field to flow into the west-to-east pipeline after 2008.

There are also plans to introduce facilities for LNG in China. BP won a contract with CNOOC to build China's first LNG terminal, in Guangdong province, to be completed in 2006 with a capacity of 3.3 million metric ton per year. The Guangdong LNG terminal is currently under construction. Australia LNG, part of North West Shelf LNG, won the long-term supply contract worth more than $10.6 billion for 3 million tons per year of LNG for 25 years, starting in 2005. CNOOC has also broken ground on another LNG terminal at Fujian, which will begin operations in 2007 with an initial capacity of 2.6 million tons per year [*45*].

India

In 2001, India consumed 0.8 trillion cubic feet of natural gas, all of which was domestically produced. The *IEO2004* reference case projects that India's consumption will grow by 4.8 percent per year on average, to 2.5 trillion cubic feet in 2025. In 2001, about 40 percent of the gas consumed was used for electricity generation, and most of the remainder was used by the petrochemical industry [*46*]. Proved reserves in India at the beginning of 2004 were estimated at 30 trillion cubic feet, up from about 27 trillion cubic feet at the beginning of 2003 [*47*].

Much of India's production comes from fields in its western offshore area. On land, the provinces of Assam, Andhra Pradesh, and Gujarat are other major producers. Smaller quantities of gas are produced in Tripura, Tamil Nadu, and Rajasthan. Around 60 percent of the natural gas produced in 2002 was associated gas. Nonassociated gas comes mostly from the western offshore fields of South Bassein and Tapti, the gas fields in Tripura, and the K.G. Basin in Andhra Pradesh. The main natural gas producers are the Oil and Natural Gas Corporation Limited (ONGCL), which concentrates on the western offshore, and the Oil India Limited (OIL), which focuses on Assam and Rajasthan. Urban centers in producing states, as well as in Gujarat and Maharashtra in northwest India, consume most of the natural gas produced. A gas pipeline grid in the south is also being considered [*48*].

The Ministry of Petroleum and Natural gas has plans for dramatic transmission growth in the near future [*49*]. The Gas Authority of India Limited (GAIL) is the government's transmission and distribution operator, with 2,700 miles of natural gas pipelines. Because production of associated gas exceeds the existing transportation capacity, ONGCL and OIL are setting up special transportation facilities to prevent flaring, which has already been reduced from 30 percent of gross production in the early 1990s to 7 percent in 2002. Domestic pipelines now in the works include a 373-mile pipeline from Visakhapatnam to Secunderabad in Andhra Pradesh, a 435-mile pipeline from Mangalore in Karnataka to Madurai in Tamil Nadu, 357 miles of pipeline to connect the Cochin LNG terminal to Kerala's infrastructure, and an extension of the 1,429-mile Hazira-Bijapur-Jagdishpur pipeline [*50*]. India recently refused to participate in a potential Middle Eastern pipeline, which would have entered India through Pakistan, for political reasons. The Qatar-Oman Dolphin pipeline project may later extend to India by an undersea route.

Over the next decade, India's demand for natural gas is projected to exceed supply. To reduce the supply gap, India has negotiated a 25-year import agreement for 7.5 million metric tons of LNG annually from Rasgas of Qatar [*51*]. Rasgas will supply the first two regasification terminals in India, at Dahej and Hazira. Both are expected to come on line in 2004, with capacities of 5.0 and 2.5 million tons per year, respectively [*52*]. Shell, BG, and other companies are competing to enter India's LNG market, negotiating innovative pricing deals with the National Thermal Power Corporation to accommodate current political difficulties involved in setting end-user tariffs. A breakdown of agreements on Enron's Dabhol project halted the completion of an LNG facility that was to begin operation in 2001. The Dabhol fracas illustrated the political risks of investing in public utilities in India [*53*].

South Korea

South Korea is the world's second largest LNG importer, after Japan. The country produces negligible amounts of natural gas domestically and in 2001 consumed 0.7 trillion cubic feet, mostly obtained through long-term import contracts. Natural gas demand in South Korea has increased markedly since the country's recovery from the 1997-1998 Asian economic crisis and is projected to increase to 1.0 trillion cubic feet in 2010 and 1.8

trillion cubic feet in 2025 in the *IEO2004* reference case, at an average annual rate or 3.9 percent. LNG demand is expected to climb as the industrial sector shifts to electric power and direct natural gas use, a trend that gained momentum from the high oil prices of 1999 [***54***]. Industrial demand makes up about 17.6 percent of South Korea's total natural gas demand, residential demand 41.4 percent, electricity generation 35.4 percent, and miscellaneous uses the remainder [***55***].

In 2003, South Korea began offshore production from Ulchin at the Donghae-1 field, which contains 200 billion cubic feet of gas [***56***]. The Korea National Oil Corporation is a substantial partner in more than a dozen gas projects around the world. In 2002, Korea's contracted sources of gas imports included Qatar (237 billion cubic feet), Indonesia (232 billion cubic feet), Oman (187 billion cubic feet), and Malaysia (106 billion cubic feet), with smaller amounts from Australia, Brunei, and the United Arab Emirates [***57***]. Following deregulation of the country's energy sector, KOGAS limited its pursuit of long-term import contracts in 2002, leaving it in part reliant on spot markets for LNG in 2003. KOGAS purchased 1.36 million metric tons of LNG on the spot market in 2002, about 9 percent of South Korea's total gas consumption [***58***].

The Korean distribution network consists of 820 miles of pipelines covering the west coast near and around Seoul, with connections to LNG terminals at Incheon and Pyongtaek. KOGAS has built an 832-mile pipeline system serving the central and west coast regions. South Korea has no international pipelines, but the government hopes to negotiate a route from Russia by 2007. China and Russia are interested in a natural gas pipeline that would run through North Korea to South Korea, which would help resolve the geopolitical issues facing North Korea, particularly concerning its use of nuclear power.

Other Developing Asia

A number of countries and companies across Asia have taken an interest in the development of natural gas markets, and several are going ahead with international agreements to access resources. In 2002, Indonesia and Malaysia were the largest natural gas producers in developing Asia, exporting 1,108 and 741 billion cubic feet of natural gas, respectively [***59***]. They accounted for about 70 percent of Asia's gas trade, both by way of pipeline (small amounts to Singapore) and as LNG (to Japan, South Korea, and Taiwan). Indonesia alone exported 22 percent of the world's traded LNG in 2002.

Indonesia, the world's largest LNG exporter, produced 2.4 trillion cubic feet of natural gas in 2001 while consuming only 1.3 trillion cubic feet [***60***]. In 2002, Indonesia exported 729 billion cubic feet of LNG (66 percent of LNG exports) to Japan, 232 billion cubic feet (21 percent) to Korea, and 147 billion cubic feet (13 percent) to Taiwan. It also piped natural gas to Singapore. LNG is processed at the country's two liquefaction plants, PT Arun LNG and Bongtang LNG. A third plant is being developed by BP at Tangguh to supply China with LNG for its Fujian regasification terminal beginning in 2007.

Like Indonesia, Malaysia has substantial natural gas reserves. At the beginning of 2004, Malaysia's proved reserves were estimated at 75 trillion cubic feet [***61***]. About 60 percent of its marketed gas production is consumed domestically, three-quarters of which is used for electricity generation. The country's largest gas field is Kinabalu, in eastern Malaysia, and its gas infrastructure includes more than 1,000 miles of transmission and distribution pipelines. Malaysia is the region's second largest LNG exporter, accounting for 14 percent of the total world trade in LNG in 2002, with exports to Japan, South Korea, Taiwan, and occasionally the United States [***62***].

Malaysia is also seeking to increase its production of natural gas. The Malaysia-Thailand Joint Development Authority administers a region that is contested by the two countries and is now being explored by Petronas and the Petroleum Authority of Thailand (PTT) as well as Amerada Hess and BP. The two countries are building a pipeline linked to a gas-fired electricity generation plant in Thailand near a connection in the two countries' grids, with plans for a future gas pipeline to Malaysia. Malaysia also has offshore fields in the South China Sea, which are being developed by ExxonMobil. Malaysia exports 9.2 billion cubic feet per year to Singapore via pipeline. In a move to position itself as Southeast Asia's gas hub, Malaysia also has begun imports of Indonesian gas from the Natuna offshore field through a connection to Malaysia's Duyong field pipeline.

Thailand developed its natural gas market rapidly in the 1990s, more than doubling its production between 1991 and 2001. Its gas reserves were estimated at 13 trillion cubic feet as of the beginning of 2004 [***63***]. In 2001, the last year of a national drive to increase gas-fired generation, 76 percent of Thailand's natural gas was used to generate electricity [***64***]. Its largest natural gas field, Bongkot, is 400 miles south of Bangkok in the Gulf of Thailand, and the government plans to expand the natural gas distribution network to reach more power plants and industrial consumers. Thailand also imports 55 billion cubic feet a year from Burma through the Yadana-Ratchaburi pipeline.

In Taiwan, a major regional consumer of natural gas, consumption grew significantly from 1990 to 2000. Of the total gas supplied to the market, 68 percent of Taiwan's natural gas supply is used for electricity generation. Taiwan imported 91 percent of its gas supply in 2002, obtaining LNG mainly under long-term agreements with Indonesia (147 billion cubic feet) and

Malaysia (100 billion cubic feet) [*65*]. Taiwan currently has one LNG import facility, Yung An. Another facility, Taoyuan, has been proposed but has not yet secured a contract with Taipower, the national utility.

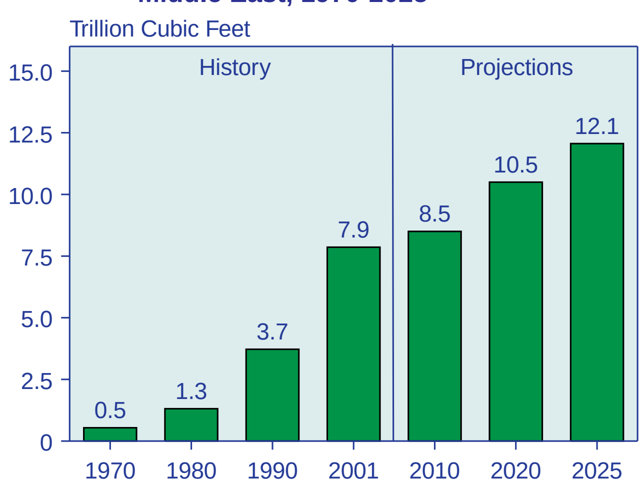
Middle East

Natural gas consumption in the Middle East rose sharply in the 1990s, from 3.7 trillion cubic feet in 1990 to 7.9 trillion cubic feet in 2001, and is projected to increase to 12.1 trillion cubic feet in 2025 (Figure 50). The average annual growth rate over the forecast period is projected to be 1.8 percent. Oil-exporting countries in the Middle East are seeking to expand natural gas use domestically so that as much oil as possible can be exported.

After Russia, Iran has the world's second largest proven natural gas reserves, at 940 trillion cubic feet. Qatar ranks third in world reserves with 910 trillion cubic feet and is becoming an important LNG supplier (see box on page 66). Despite its abundant reserves, Iran has imported natural gas for the past several years, because its major population centers are in the north, far from its reserves in the Persian Gulf. The government of Iran is working aggressively to address this discrepancy and begin monetizing its assets. Natural gas consumption in Iran grew from 883 billion cubic feet in 1992 to 2.3 trillion cubic feet in 2001. About 2.2 trillion cubic feet of natural gas was brought to market in 2002, and an additional 1.5 trillion cubic feet was flared or reinjected [*66*].

Natural gas supplies about half of Iran's total energy consumption, and the government hopes to increase gas-fired electricity generation to free other petroleum products for export. Of Iran's total marketed natural gas consumption, 36.1 percent is used for electricity generation, 22.8 percent goes to industrial uses, 28.8 percent to the residential sector, and 3.8 percent to the commercial sector. The remainder is accounted for by autoconsumption and distribution losses [*67*].

Figure 50. Natural Gas Consumption in the Middle East, 1970-2025



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

The South Pars field is geologically divided between Qatar and Iran. The Iranian Oil Ministry estimates that South Pars eventually will produce up to 8 billion cubic feet per day and can earn Iran $11 billion annually for 30 years. TotalFinaElf, Malaysia's Petronas and Russia's Gazprom are key developers of South Pars. Petronas spent $8 billion on the development of South Pars in 2003, but expansion plans have lagged due to technical and commercial obstacles. Russian contractors are building a 56-inch, 300-mile pipeline to feed into Iran's national gas grid [*68*]. Currently, South Pars gas runs to onshore refining facilities at Asaluyeh, where Hyundai is building four gas-processing trains for LNG exports.

The government and private investors are working to build LNG facilities in Iran. Currently there are four proposals, ranging in size from 8.0 to 10.0 million metric tons of LNG exports per year. The Oil Ministry expects to begin supplying the domestic market by 2007 and to begin LNG exports by 2008. The Iranian government is hoping to boost gas production from 3.9 trillion cubic feet in 2000 to 10 trillion cubic feet in 2010 [*69*]. Although no firm commitments have yet been made, Iran has the potential to become a major supplier of natural gas to Europe in the future. At least four two-train LNG liquefaction projects are being evaluated by the Iranian government, each with a capacity of 390 to 490 billion cubic feet per year. Iran has also recently completed a pipeline link to Turkey, which it hopes is the first step toward providing supplies to Europe.

A gas pipeline between Iran and Turkey was inaugurated in January 2002. While the pipeline could carry as much as 350 billion cubic feet by 2007, there are concerns as to the robustness of future Turkish demand in light of potentially competing imports from Russia, Algeria, and Nigeria.

Saudi Arabia has the world's fourth largest proved gas reserves, after Russia, Iran, and Qatar. About 40 percent of Saudi Arabia's 231 billion cubic feet of gas reserves consists nonassociated gas. The Saudi government and the state-controlled national oil and gas company, Aramco, are developing the domestic gas market—particularly to fuel the growing petrochemical industry—in order to free oil resources for export. The government has chosen this strategy to mobilize its natural resources rather than actively joining the race to export LNG. Industrial centers fed by the Saudi gas system include Yanbu on the Red Sea and Jubail, which supply 10 percent of the world's petrochemical production. The Hawiyah natural gas processing plant produces 1.5

Qatar LNG: Status and Developments

By 2010 Qatar is expected to be one of the world's leading producers of LNG. The country has been very successful in finding new markets. In 2002, Qatar earned around $3.7 billion from exporting 15 million metric tons of LNG.[a] At the LNG Ministerial Summit in December 2003, sponsored by the U.S. Department of Energy, Qatar's energy minister announced that his country will invest some $25 billion in LNG projects by 2010, quadrupling its export capacity.[b]

Qatar is a relatively new supplier of LNG, shipping its first LNG to Japan in 1997. Its focus is the Asian market, the proximity of which has been strategic to profitability. As technology has reduced the cost of liquefaction and shipping by almost a third in the last few years, Qatar has become the focus of attention as it negotiates projects that will expand its market share in Asia and allow it to enter the Western market.

With proven reserves of over 900 trillion cubic feet, Qatar's natural gas resources rank third in size behind Russia's and Iran's.[c] Most of the country's reserves are located in the North Field, to date the largest known non-associated gas field in the world. Qatar began developing the North Field gas reserves in 1984, for the most part producing condensates.[d] In addition, the Dukhan field and smaller associated gas reserves in the Id al Shargi, Maydan Mahzam, Bul Hanine, and al-Rayyan oil fields are estimated to contain 10 trillion cubic feet of gas.

For the last few years the Qataris have opted to diversify their gas portfolio by investing in regional gas pipeline projects, gas-to-liquid technology, and the expansion of their liquefaction capacity. The most ambitious regional pipeline project to date is the $4 billion Dolphin Gas project that will pipe gas over 260 miles from Qatar to the United Arab Emirates (UAE) and Oman, delivering an estimated 2 billion cubic feet per day by 2006.[e] Though these importing countries have their own reserves, and export LNG themselves, they find it less costly to import Qatari gas than to develop and treat their own non-associated gas supplies. Kuwait and Bahrain, two other Gulf States, have also approached Qatar with a view to follow suit.

Qatar has also invested in gas-to-liquid technology (GTL). This approach, developed at great cost, converts natural gas into high-grade gasoline and distillates. Qatar has already drawn up plans to produce 174,000 barrels per day. It is expected that its project with *Sasol*, the South African oil company, will produce 34,000 barrels per day by 2005; according to current estimates another venture with Shell International will produce 140,000 barrels per day by 2007.[f]

Currently, Qatar has two LNG export projects that serve mainly the Asian market:

- *Qatar Liquefied Gas Company Limited (QatarGas).* The first of this three-train project went on stream in 1996. Partners comprise the state-owned Qatar Petroleum (QP), which has a majority interest, ExxonMobil, Total, Marubeni, and Mitsui. At present, the project has a capacity of around 8 million metric tons per year; after debottlenecking is completed in 2005, it will reach 9.5 million metric tons per year. In addition, QatarGas has long-term contracts for the sale of 4 million metric tons per year to Chubu Electric Company in Japan and another 2 million metric tons per year to seven other Japanese electric and gas utilities. It also delivers spot cargoes to Europe and the United States.
- *Ras Laffan Liquefied Natural Gas Company Limited (RasGas).* With a current capacity of 6.6 million metric tons per year, RasGas sells 4.8 million metric tons per year to Korea Gas under a long-term contract. Two more trains are presently under construction, each with a 4.7 million metric tons per year capacity. Of this, 7.5 million metric tons per year will go to India under a 25-year contract, with additional volumes available for spot sales. Participants in the first phase of RasGas are QP, ExxonMobil, Itochu, and LNG Japan, though only QP and ExxonMobil are involved in the expansion phase.[g]

(continued on page 67)

[a]World Market Research Centre, "Country Reports—Qatar" (December 2003), web site www.wmrc.com.
[b]Personal communication with Abdullah bin Hamad Al-Attiyah, Minister of Energy & Industry, State of Qatar (Washington, DC, December 18, 2003).
[c]Embassy of Qatar, *Qatar: The Modern State* (Washington, DC, November 2003).
[d]Condensate is a light hydrocarbon liquid that is suspended in natural gas reservoirs and can be recovered by condensation of hydrocarbon vapors. After it is separated from the gas, it remains liquid without pressurized or refrigerated containment.
[e]Personal communication with Khaldoon Al Mubarak, Executive President of Dolphin Energy Limited (Washington, DC, December 18, 2003).
[f]Energy Information Administration, *Country Analysis Brief: Qatar* (November 2003), web site www.eia.doe.gov/emeu/cabs/qatar.html.
[g]Personal communication with Colleen Taylor-Sen, Senior LNG Advisor, Gas Technology Institute (Washington, DC, December 18, 2003).

Qatar LNG: Status and Developments (Continued)

Other projects have also been proposed. In 2003, Qatar signed two agreements: one with ExxonMobil, to provide the United Kingdom with 15 million metric tons per year by 2006-2007; and a second, with ConocoPhillips, to provide 9.2 million metric tons per year by 2008-2009, 7.5 million metric tons of which is to be destined for the United States. Total is negotiating a similar volume (9.2 million metric tons per year) with QatarGas, also for delivery by 2008-2009; ExxonMobil too is working on providing an additional 15 million metric tons per year for the United States by 2010.[h] In all of these projects, Qatar intends partnering international companies across the entire spectrum, ranging from production to liquefying, transporting, regasifying, distributing, etc.

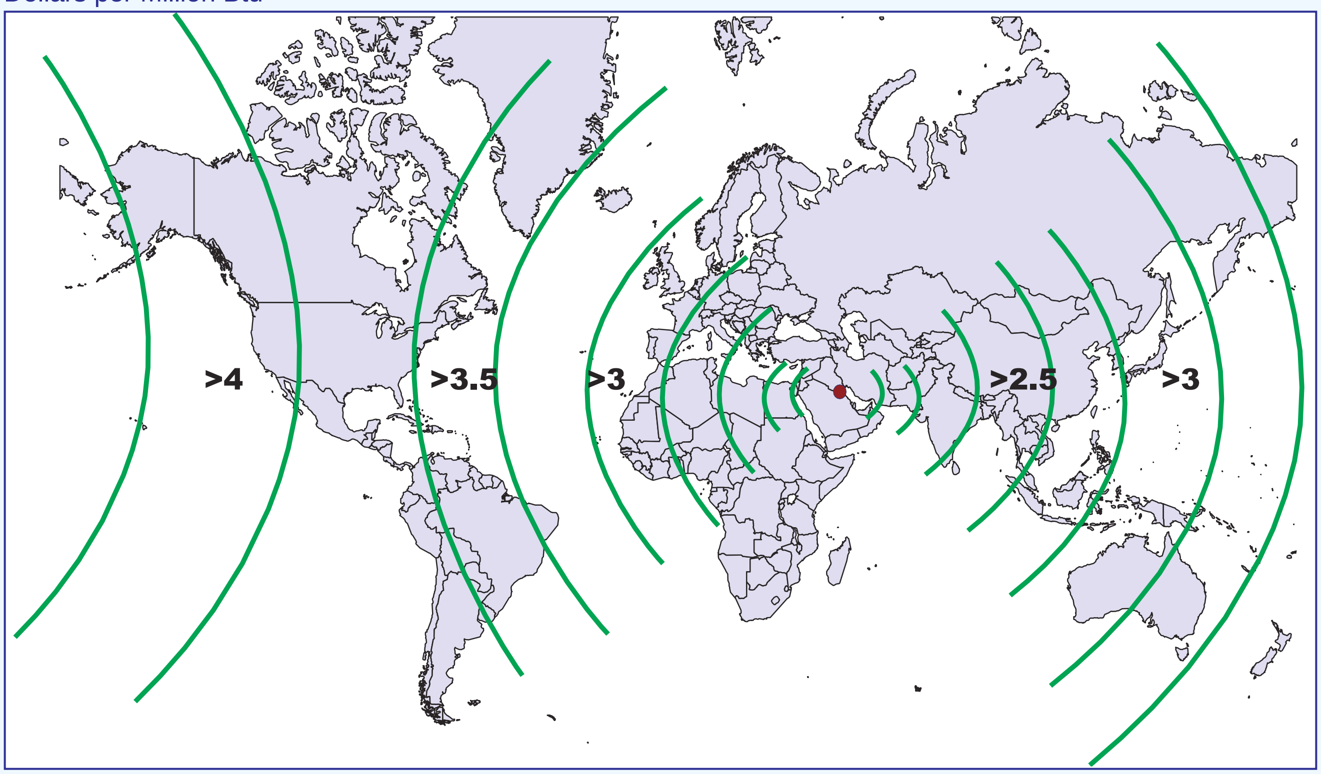
Qatar LNG is expected to occupy a leading position in the United States market over the next two decades. For the next 6 years, with the U.S. average annual wellhead price of gas not expected to be lower than $ 3.50 per million Btu, Qatar will be in a position to recover its costs in the U.S. market (see map below).

The Middle East has the lowest exploration and development costs for gas of any region in the world, with capital costs estimated at less than $0.20 per million Btu.[i] Even though most of Qatar's gas is offshore, the transmission pipelines to connect the gas fields to the LNG liquefaction plants are relatively short, comprising only a small share of the overall cost. An added bonus is that most of the proposed liquefaction projects are in Ras Laffan Industrial City, where they take advantage of existing infrastructures and large amounts of land available for development, additional factors that keep spending down. Technological advances are such that the capacity of the new trains might reach 7 million metric tons per year (prior to this the limit was 2 to 3 million metric tons). Once economies of scale are factored in, the competitiveness of Qatar's LNG should continue to increase.

In order to finance its current projects, Qatar maintains and enjoys a strong credit rating, despite regional

(continued on page 68)

Benchmark Price Requirements for LNG Shipments from Qatar
Dollars per Million Btu



Source: Adapted from Cambridge Energy Research Associates.

[h]Energy Information Administration, *The Global Liquefied Natural Gas Market: Status & Outlook*, DOE/EIA-0637(2003) (Washington, DC, December 2003), web site www.eia.doe.gov/oiaf/analysispaper/global/pdf/eia_0637.pdf.
[i]International Energy Agency, *World Energy Investment Outlook 2003* (Paris, France, 2003), p. 228, web site www.worldenergyoutlook.org.

Qatar LNG: Status and Developments (Continued)

unrest.[j] Qatar's infrastructure is safer than in most nearby countries because it hosts U.S. military bases.[k] Costs for Qatar's new liquefaction facilities will therefore remain stable, despite the region's strife.

Although LNG imports in 2002 comprised only about 1 percent of the U.S. market, this amount will increase substantially over the next two decades. At present there are four terminals in the continental United States that receive LNG, with a total capacity of about 3 billion cubic feet per day. By 2025 the projected increase is estimated at 14 billion cubic feet per day, necessitating at least 10 more terminals. In fact the major challenge regarding the future of LNG in the United States is not the availability of terminals (a need that is slowly being met), rather it is the reliability of supply. Equally important, there is also the matter of transparent and sustainable rules governing the gas business per se.[l]

A major concern to a supplier such as Qatar is the uncertainty regarding U.S. restructuring of the gas and electric power industries. LNG suppliers see deregulation as a disadvantage, because it is likely to result in changes to the business environment, such as the insistence on shorter contracts, the removal of the take-or-pay clauses and fixed destination from future contracts, and requiring third-party access to regasification facilities. These changes force suppliers to shoulder a greater portion of the risk, which might hinder the development of liquefaction facilities.

The U.S. regulatory body, the Federal Energy Regulatory Commission (FERC), has lately eased its requirement for open access to regasification capacity. This development has encouraged potential suppliers such as Qatar and its major partners to consider investing in new terminals. At present, many LNG investors who have been monitoring the Henry Hub index of natural gas prices are eager to capture what appears to be a high margin of profitability in supplying LNG to the U.S. market. Although Henry Hub index prices have been higher than the cost of LNG imported to the United States for the past 4 years, some observers believe that the index does not reflect market realities, and may encourage over-investment in LNG that will not be economically sustainable.

LNG projects are multi-billion-dollar undertakings, and at this point it is unclear whether Qatar will be willing to accept the high financial risks associated with increasing its LNG capacity to supply the North American market.

[j]International Energy Agency, *World Energy Investment Outlook 2003* (Paris, France, November 4, 2003), p. 231.
[k]World Market Research Centre, "Country Reports—Qatar" (March 2004), web site www.wmrc.com.
[l]Personal communication with Ibrahim B. Ibrahim, Chairman of Marketing and Vice Chair of the Board of Qatar RasGas Company (Washington, DC, December 18, 2003).

billion cubic feet of gas per day, enough to displace 260,000 barrels per day of Arabian light crude oil from domestic consumption. The Haradh processing plant, which came on line in 2003, increased the country's natural gas processing capacity by 20 percent, to 9.5 billion cubic feet per day [***70***].

Starting in 1999, Aramco has been developing a 25-year, $45 billion initiative to expand Saudi Arabia's upstream gas industry. Aramco's exploration aims to increase reserves by 3 to 5 trillion cubic feet per year to meet growing domestic demand for natural gas. One-quarter of the country's gas production goes to petrochemical producers (fuel gas and feedstock for producing plastics and industrial chemicals for export), one-fifth to desalination plants, and one-fifth to the oil industry in support of the expanding Master Gas System capacity [***71***].

The Saudi government has been in talks with major international energy companies to open the country to upstream development as part of the Saudi Gas Initiative. The aim of the program is to integrate upstream gas development with downstream petrochemicals, power generation, and water desalination, in part through greater foreign investment. Talks broke down in the summer of 2003, however, over issues of access to reserves and potential rates of return to investors. Saudi officials hope to have 1,200 miles of transmission pipeline in place by 2006 and to raise natural gas output to 15 billion cubic feet per day by 2009 [***72***].

Oman's natural gas consumption totaled 224 billion of cubic feet in 2001, an 80.5-percent increase from a decade earlier. In the same period, its natural gas production doubled [***73***]. Oman has 29 trillion cubic feet of proved reserves [***74***], and the government is aggressively pursuing growth in its gas industry, in part to diversify its economic dependence on oil exports; however, much of its gas reserves are trapped in complex geologic structures near oil fields [***75***].

The Oman Gas Company runs the national transmission network, consisting of one 500-mile trunk line and several pipelines connecting gas fields to an electricity facility in Salalah, which came on line in 2004. A second pipeline, scheduled to open in 2006, will transport gas from a site near Muscat to a new refinery in Sohar [***76***]. Enbridge, BC/Terasen Gas International, and Oman

Holding International won a 5-year, $23 million contract to run the nation's 1,100-mile distribution system. Oman is also participating in the $3.5 billion deepsea Dolphin pipeline [*77*], which will link Qatar with Oman and the United Arab Emirates and eventually with the South Asian subcontinent.

Oman LNG, another public-multinational partnership, which includes Shell, Total, and Korea LNG, runs the liquefaction plant at Qalhat with a capacity of 7.3 million metric tons per year [*78*]. Ongoing efficiency improvements are expected to increase production by 15 percent per year. Gas is delivered through three major LNG contracts: an agreement with KOGAS for 4.1 million metric tons per year; a contract with Osaka Gas Company for 0.7 million metric tons per year; and a contract with Metgas to supply India's Dabhol project with 1.6 million metric tons per year. The last two agreements are not yet in effect, and Oman is selling LNG on the global spot market [*79*].

In recent years Turkey has moved to preempt expected increases in international and domestic natural gas demand by fostering international pipeline infrastructure, which may eventually connect producers in the Middle East and northern African to Europe's natural gas grid. In February 2003, as part of an effort to integrate hydrocarbon transport networks in the region, Greece and Turkey signed an agreement to construct a 176-mile pipeline, to begin operation in 2005 with an initial capacity of 17.6 billion cubic feet [*80*].

Turkey's gas demand has climbed rapidly over the past decade, from 164 billion cubic feet in 1992 to 563 billion cubic feet in 2001. Turkey's April 2001 passage of a gas market reform program has brought it closer to accord with EU market practices and closer to a competitive gas market intended to encourage private investment. Almost all the natural gas consumed in Turkey is imported from four countries: Russia, Iran, and LNG from Algeria and Nigeria. Turkey's LNG imports come in from Ereglisi on the Sea of Marmara, which received 172 billion cubic feet of LNG in 2002 [*81*]. In 2002, Turkey imported 621 billion cubic feet of gas [*82*].

Africa

Natural gas consumption in Africa is projected to increase from 2.3 trillion cubic feet in 2001 to 4.6 trillion cubic feet in 2025, at an average rate of 3.0 percent per year (Figure 51). Africa is a net exporter of natural gas, primarily from Algeria, Nigeria, and Libya. In 2002, LNG exports from those three countries accounted for about 23 percent of the natural gas traded in the world and 52 percent of Africa's natural gas production. More than 85 percent of Africa's gas exports went to Western Europe, with some LNG exports also going to the United States. Many countries in Africa have significant untapped production and export potential, and with Western European demand rising, international energy companies are rapidly expanding investment in the region.

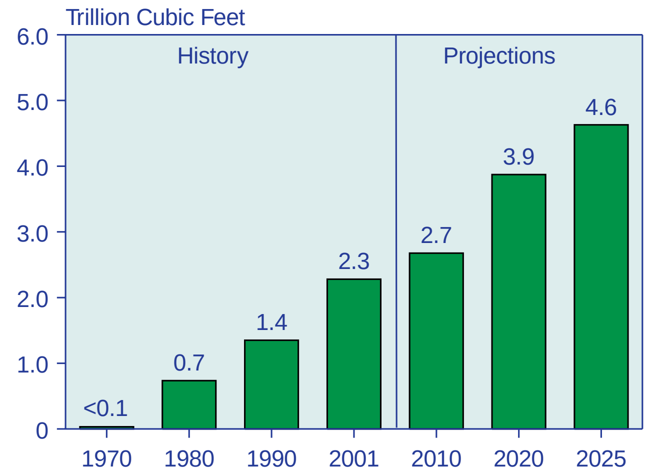
Algeria

Algeria is the world's second largest LNG producer, after Indonesia, and the fourth largest exporter of natural gas, after Russia, Canada, and Norway. In 2001, Algeria produced 2.84 trillion cubic feet of natural gas, while its consumption totaled 788 billion cubic feet. Its consumption has grown moderately since the beginning of the 1990s, fluctuating between 650 and 800 billion cubic feet [*83*]. Algeria holds 35 percent of Africa's proved reserves, about 160 trillion cubic feet [*84*]. In 2002, Algeria exported 2 trillion cubic feet of gas through pipelines and as LNG.

About 72 percent of Algeria's gas exports go to southern European and Mediterranean countries and 23 percent to the rest of Europe. Sonatrach, Algeria's state-owned oil and gas company, is responsible for overseeing gas production and sales to foreign buyers and domestic industries. One-fourth of Algerian natural gas comes from the Hassi R'Mel field, which produces 1.4 billion cubic feet per day. The remainder comes from the southeast and the southern In-Salah region.

Sonatrach's management and labor unions have blocked petroleum market proposals that would have removed Sonatrach's monopoly or changed its regulatory status. As a result, foreign companies may find it easier to make investments to export large quantities of natural gas in the near term, because they will be able to continue to

Figure 51. Natural Gas Consumption in Africa, 1970-2025



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

negotiate with only one partner. Had the reform proposals been passed, the foreign companies would have had to negotiate with several successor companies formed by divesting Sonatrach; however, the prices charged to foreign companies for natural gas might have been reduced if the transition to competition had been completed [*85*].

Algeria has a well-developed transportation infrastructure, including 4,300 miles of domestic pipeline and 1,460 miles of international pipeline. The two largest international pipelines are the Trans-Mediterranean (Transmed) pipeline, at 900 billion cubic feet per year, and the Maghreb-Europe Gas (MEG) pipeline, at 350 billion cubic feet per year. The Transmed comprises segments through Algeria, Tunisia, and under the Mediterranean to Sicily and mainland Italy, with an extension into Slovenia. Tunisia purchases about 39 billion cubic feet per year, Slovenia's Sozd Petrol is committed to 21 billion cubic feet, and Italy's main gas utility, Snam, is under contract to buy 680 billion cubic feet until 2018 [*86*]. Planned upgrades would increase the capacity of the Transmed pipeline to 1.0 trillion cubic feet per year [*87*].

The MEG pipeline runs from Hassi R'Mel to the Iberian Peninsula via Morocco, carrying 350 billion cubic feet per year for 1,013 miles. It runs 168 miles across the Strait of Gibraltar, sometimes at a depth of 1,312 feet, to Cordoba, Spain, and ties into the Spanish and Portuguese transmission networks. Planned upgrades will augment MEG's transmission capacity to 460 billion cubic feet per year in late 2004. The Medgaz consortium also has plans to build a new 279-mile pipeline between Algeria and Spain, to come on line in 2006, which would carry 282 billion cubic feet of gas per year, with the possibility of future expansion to 420 billion cubic feet.

In addition, Algeria has two LNG plants with a combined annual liquefaction capacity of 23 million metric tons of LNG, or 1,125 billion cubic feet of gas. In 2003, BP won a contract to partner with Sonatrach to supply 5 percent of the United Kingdom's LNG market starting in 2005 [*88*].

Nigeria

Nigeria is the second largest LNG exporter on the African continent and the fifth largest in the world. The country produced 394 billion cubic feet of natural gas in 2002. Its domestic consumption increased from 168 billion cubic feet in 1991 to 277 billion cubic feet in 2001, an increase of 65 percent [*89*]. At the beginning of 2004, Nigeria's proved reserves were estimated at 159 trillion cubic feet [*90*].

One-half of Nigeria's gross natural gas production is flared, and another 12 percent is reinjected to improve oil production operations. The development of the Bonny LNG facility and the 40-percent increase in gas usage by the petrochemical industry over the past decade are beginning to generate a market for natural gas resources [*91*].

Nigeria's LNG plant at Bonny Island currently has three trains with a capacity of 9.5 million metric tons per year. Two additional trains under construction will add an additional 8.2 million metric tons in 2005, and a sixth train has been proposed for mid-2006. Three new LNG plants—West Niger Delta, Brass River LNG, and a floating LNG plant—have been proposed. If funded, they would come on line between 2008 and 2010 [*92*].

Egypt

Egypt will soon emerge as a major African exporter fueling Europe's expanding demand for natural gas. The Western Desert, the Nile Delta, and offshore regions hold significant potential for natural gas development. Egypt's proved natural gas reserves total 59 trillion cubic feet, and its expected reserves are much larger. Egypt produced about 3 billion cubic feet of gas per day in 2002 and expects to produce 5 billion cubic feet per day by 2007.

To develop private investment and joint venture deals, the government set up the Egyptian Natural Gas Holding Company, splitting it from the Egyptian General Petroleum Company (EGPC) in April 2001. The International Egyptian Oil Company, a subsidiary of the Italian energy group Eni-Agip, is Egypt's leading gas producer. BG, BP, Shell, and Apache also produce gas in Egypt.

Spain's Union Fenosa and EGPC are building Egypt's first LNG facility at the port of Damietta, to be completed by the end of 2004. It is slated for a single train with a capacity of 5.0 million metric tons and potential for additional trains [*93*]. The project will purchase gas from the EGPC grid and ship LNG to Union Fenosa's associate power plants. A second Egyptian LNG facility at Idku is being built by EGPC, BG, Gaz de France, and Petronas. The first train is set to come on line in 2005 and is contracted to deliver 3.6 million metric tons per year to Gaz de France for 20 years. The Idku complex can house up to six trains, and the second train, funded by EGPC, BG, and Petronas, is already under construction and slated to open in 2006. The entire capacity of the second train is contracted to BG through 2007 [*94*].

Egypt is also beginning to export natural gas via pipeline to the Middle East. The first phase of the Middle East Gas Pipeline Project was completed in January 2004, linking the city of Aqaba in Jordan to Egypt's gas distribution network. The second phase will extend approximately 230 miles from Aqaba to a power plant in northern Jordan by 2005. The pipeline could be extended to Syria and Lebanon by 2006 [*95*].

Other Africa

Libya's reincorporation into the international community in 2003 has created the potential for it to become another large African exporter of natural gas. It has been exporting LNG to Spain since 1970 from its Marse el-Brega facility, but lack of technical capacity and capital has limited its exports to around 30 billion cubic feet per year. Libya's proved natural gas reserves were estimated at 46 trillion cubic feet in 2004, but it is likely that its actual resources are far greater.

Despite a 1,000-mile pipeline network, the Libyan grid is inadequate to serve growing demand. The network has a cumulative capacity of 353 billion cubic feet of gas, with the largest capacity contribution, 144 million cubic feet per day, from the Costal pipeline that runs from Marse el-Brega to Bukkamash. There are plans to build additional transmission capacity to serve power generation in Khoms, Benghazi, Zueitina, and Tripoli.

Engas, the Spanish Utility, is the only current major foreign consumer of Libyan gas. Eni and the government energy company have started developing the $5 billion Western Libyan Gas Project (WLGP). In June 2002, an Eni affiliate won a $500 million contract to build an offshore facility near Tripoli. The WLGP is expected to export 280 billion cubic feet of gas per year from Melitah to Italy and France beginning in 2006 via a 370-mile pipeline under the Mediterranean Sea. Gaz de France and Italy's Edison Gas and Energia have signed agreements to receive 140 billion cubic feet of the exported gas, mostly for power generation.

While Angola is a major international oil producer, it lacks the infrastructure to harness much of its natural gas resources. Currently, 59 percent of the gross associated gas produced in Angola is flared and 31 percent is reinjected for oil production [***96***]. The government aims to spend $2 billion to end flaring from offshore facilities, including plans to build a new LNG plant near Luanda in the South Lower Congo Basin in order to develop its natural gas resources for domestic and external use [***97***]. The state-owned oil company, Sonangol, has partnered with ChevronTexaco to develop an LNG facility capable of exporting 4 million metric tons per year by 2005. TotalFinaElf, Norsk Hydro, BP, and ExxonMobil will participate in the project, contributing gas from their deepwater facilities. The government of Namibia and Shell are considering similar investments from Shell's offshore Kudu gas field [***98***].

Other natural gas producers in Africa with noteworthy marketed quantities in 2002 include Tunisia (79.4 billion cubic feet), South Africa (74.1 billion cubic feet), Côte d'Ivoire (47.7 billion cubic feet), and Equatorial Guinea (44.8 billion cubic feet). Gabon, Cameroon, and Congo produce significant amounts of natural gas as a byproduct of oil operations but flare or reinject almost all of it [***99***].

References

1. BP, p.l.c., *BP Statistical Review of World Energy* (London, UK, June 2003), pp. 25 and 28.
2. "Worldwide Look at Reserves and Production," *Oil & Gas Journal*, Vol. 101, No. 49 (December 22, 2003), pp. 46-47.
3. M. Radler, "Worldwide Reserves Grow; Oil Production Climbs in 2003," *Oil & Gas Journal*, Vol. 101, No. 49 (December 22, 2003), pp. 44-45.
4. BP, p.l.c., *BP Statistical Review of World Energy* (London, UK, June 2003), p. 20.
5. Energy Information Administration, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004).
6. Energy Information Administration, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004).
7. Energy Information Administration, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004).
8. Energy Information Administration, "Country Analysis Briefs: United Kingdom," web site www.eia.doe.gov (February 2003).
9. "Worldwide Look at Reserves and Production," *Oil & Gas Journal*, Vol. 101, No. 49 (December 22, 2003), pp. 46-47.
10. Energy Information Administration, *The Global Liquefied Natural Gas Market: Status & Outlook*, DOE/EIA-0637(2003) (Washington, DC, December 2003).
11. Energy Information Administration, "Country Analysis Briefs: Japan," web site www.eia.doe.gov (July 2003).
12. Asian Pacific Energy Research Centre, Institute of Energy Economics, *Natural Gas Market Reform in the APEC Region* (Tokyo, Japan, 2003), pp. 89-91.
13. World Markets Research Centre, "Energy Brief: Japan," web site www.worldmarketsanalysis.com (August 27, 2003).
14. International Energy Agency, *Energy Balances of OECD Countries, 2000-2001* (Paris, France, 2003).
15. "Worldwide Look at Reserves and Production," *Oil & Gas Journal*, Vol. 101, No. 49 (December 22, 2003), pp. 46-47.
16. Energy Information Administration, *The Global Liquefied Natural Gas Market: Status & Outlook*, DOE/EIA-0637(2003) (Washington, DC, December 2003).
17. BP, p.l.c., *BP Statistical Review of World Energy* (London, UK, June 2003), p. 20.

18. Cedigaz, "2002 Natural Gas Statistics: Estimates of Gross and Marketed Natural Gas Production" (April 2003), Table 2, web site www.cedigaz.com.

19. Cedigaz, "2002 Natural Gas Statistics: Estimates of Gross and Marketed Natural Gas Production" (April 2003), Tables 5 and 9, web site www.cedigaz.com.

20. Energy Information Administration, "Country Analysis Briefs: Russia," web site www.eia.doe.gov (September 2003).

21. "Worldwide Look at Reserves and Production," *Oil & Gas Journal*, Vol. 101, No. 49 (December 22, 2003), pp. 46-47.

22. Energy Information Administration, *The Global Liquefied Natural Gas Market: Status & Outlook*, DOE/EIA-0637(2003) (Washington, DC, December 2003).

23. Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003).

24. "Worldwide Look at Reserves and Production," *Oil & Gas Journal*, Vol. 101, No. 49 (December 22, 2003), pp. 46-47.

25. World Markets Research Centre, "Brazil: Petrobras' Santos Discovery Could Triple Brazil's Gas Reserves," web site www.worldmarketsanalysis.com (September 4, 2003).

26. "Worldwide Look at Reserves and Production," *Oil & Gas Journal*, Vol. 101, No. 49 (December 22, 2003), pp. 46-47.

27. Energy Information Administration, "Country Analysis Briefs: Brazil," web site www.eia.doe.gov (July 2003).

28. "Brazilian Government Acknowledges Threat of New Energy Crisis," *Alexander's Gas & Oil Connections*, Vol. 8, No. 15 (August 8, 2003).

29. "Worldwide Look at Reserves and Production," *Oil & Gas Journal*, Vol. 101, No. 49 (December 22, 2003), pp. 46-47.

30. Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003); and "Worldwide Look at Reserves and Production," *Oil & Gas Journal*, Vol. 101, No. 49 (December 22, 2003), pp. 46-47.

31. International Energy Agency, *South American Gas: Daring to Tap the Bounty* (Paris, France, 2003), p. 44.

32. "Worldwide Look at Reserves and Production," *Oil & Gas Journal*, Vol. 101, No. 49 (December 22, 2003), pp. 46-47.

33. U.S. Geological Survey, *World Petroleum Assessment 2000*, web site http://greenwood.cr.usgs.gov/energy/WorldEnergy/DDS-60.

34. Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003).

35. World Markets Research Centre, "Venezuela: Venezuelan Oil Sector Shrinks by 2.9% in Q2 2003," web site www.worldmarketsanalysis.com (September 3, 2003).

36. Energy Information Administration, "Country Analysis Briefs: Venezuela," web site www.eia.doe.gov (May 2003).

37. International Energy Agency, *South American Gas: Daring to Tap the Bounty* (Paris, France, 2003), p. 70.

38. International Energy Agency, *South American Gas: Daring to Tap the Bounty* (Paris, France, 2003), p. 193.

39. "Unitization MOU with Venezuela to Have Far Reaching Consequences," *Cedigaz News Report*, Vol. 42, No. 35 (September 8, 2003), p. 4.

40. World Markets Research Centre, "Bolivian Unions Call General Strike in Solidarity with Gas Protests," web site www.worldmarketsanalysis.com (September 26, 2003).

41. "US, Mexico Gas Progress," *World Gas Intelligence*, Vol. 14, No. 35 (August 20, 2003).

42. Petrochina, *Overview of Petrochina's Business and Production* (2001).

43. China National Offshore Corporation, "Upstream Business Review," web site www.cnooc.com.cn/english/business/index. html.

44. "Construction Commences on Xhongxian-Wuhan Gas Pipeline," *Oil & Gas Journal Online* (September 2, 2003), web site www.ogj.com.

45. "Platts Features—Natural Gas: LNG Asia-Pacific: China," *Platts Global Energy*, web site www.platts.com (2003).

46. International Energy Agency, *Energy Balances of Non-OECD Countries, 2000-2001* (Paris, France, 2003).

47. "Worldwide Look at Reserves and Production," *Oil & Gas Journal*, Vol. 101, No. 49 (December 22, 2003), pp. 46-47.

48. Indian Ministry of Petroleum and Natural Gas, "Natural Gas: Overview," web site http://petroleum.nic.in/ng.htm (2003).

49. World Markets Research Centre, "Indian Government Releases Gas Pipeline Policy," web site www.worldmarketsanalysis.com (September 30, 2003).

50. World Markets Research Centre, "Country Report—India (Energy): Oil and Gas," web site www.worldmarketsanalysis.com (May 27, 2003).

51. "RasGas Tran-III to India to Go On Stream in 2004," *Project Monitor* (September 27, 2003).

52. Energy Information Administration, *The Global Liquefied Natural Gas Market: Status & Outlook*, DOE/EIA-0637(2003) (Washington, DC, December 2003).

53. U.S. House of Representatives, Committee on Government Reform, Minority Office, "Fact Sheet: Background on Enron's Dabhol Power Project," web site www.house.gov/reform/min (February 22, 2002).

54. I. Na, K. Yongduk, et al., *Quarterly Energy Outlook: 2Q03* (Seoul, South Korea: Korean Energy Institute, August 5, 2003).

55. Korea Gas Corporation (KOGAS), "Natural Gas Sales by Sector, 2001," web site www.kogas.or.kr (2001).

56. "Platts Features—Natural Gas: LNG Asia-Pacific: China," *Platts Global Energy*, web site www.platts.com (2003).

57. Energy Information Administration, *The Global Liquefied Natural Gas Market: Status & Outlook*, DOE/EIA-0637(2003) (Washington, DC, December 2003).

58. T. Suzuki and T. Morikawa, *Natural Gas Supply Trends in the Asia Pacific Region* (Tokyo, Japan: Institute of Energy Economics, October 2003).

59. Energy Information Administration, *The Global Liquefied Natural Gas Market: Status & Outlook*, DOE/EIA-0637(2003) (Washington, DC, December 2003).

60. Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003).

61. "Worldwide Look at Reserves and Production," *Oil & Gas Journal*, Vol. 99, No. 52 (December 21, 2001), pp. 126-127.

62. Energy Information Administration, *The Global Liquefied Natural Gas Market: Status & Outlook*, DOE/EIA-0637(2003) (Washington, DC, December 2003).

63. "Worldwide Look at Reserves and Production," *Oil & Gas Journal*, Vol. 101, No. 49 (December 22, 2003), pp. 46-47.

64. International Energy Agency, *Energy Balances of Non-OECD Countries, 2000-2001* (Paris, France, 2003).

65. Energy Information Administration, *The Global Liquefied Natural Gas Market: Status & Outlook*, DOE/EIA-0637(2003) (Washington, DC, December 2003).

66. Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003).

67. International Energy Agency, *Energy Balances of Non-OECD Countries, 2000-2001* (Paris, France, 2003).

68. TotalFinaElf, "South Pars: A Giant Gas Field Off the Iranian Coast," *Webzine 04*, web site www.total.com/webzin4/anglais/index.htm (2004).

69. Petroenergy Information Network, "South Pars Exports Over 35m Barrels of Gas Condensates," web site www.shana.ir (October 11, 2003).

70. Saudi Aramco, "Gas Operations: Latest Developments," web site www.saudiaramco.com (2003).

71. Saudi Aramco, "Gas Operations: Challenges," web site www.saudiaramco.com (2003).

72. Energy Information Administration, "Country Analysis Briefs: Saudi Arabia," web site www.eia.doe.gov (June 2003).

73. Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003).

74. "Worldwide Look at Reserves and Production," *Oil & Gas Journal*, Vol. 101, No. 49 (December 22, 2003), pp. 46-47.

75. Energy Information Administration, "Country Analysis Briefs: Oman," web site www.eia.doe.gov (October 2003).

76. World Markets Research Centre, "Country Brief: Oman, Energy," web site www.worldmarketsanalysis.com (October 2, 2003).

77. "UAE and Oman Gas Networks to be Connected Soon," *Alexander's Gas & Oil Connections*, Vol. 8, No. 19 (October 2, 2003).

78. Energy Information Administration, *The Global Liquefied Natural Gas Market: Status & Outlook*, DOE/EIA-0637(2003) (Washington, DC, December 2003).

79. World Markets Research Centre, "Country Brief: Oman, Energy," web site www.worldmarketsanalysis.com (October 2, 2003).

80. Associated Press, "Greece and Turkey Sign Gas Pipeline Deal," News Release (March 20, 2003).

81. Energy Information Administration, *The Global Liquefied Natural Gas Market: Status & Outlook*, DOE/EIA-0637(2003) (Washington, DC, December 2003).

82. Cedigaz, "2002 Natural Gas Statistics: Estimates of Gross and Marketed Natural Gas Production" (April 2003), Table 9, web site www.cedigaz.com.

83. Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003).

84. "Worldwide Look at Reserves and Production," *Oil & Gas Journal*, Vol. 101, No. 49 (December 22, 2003), pp. 46-47.

85. World Markets Research Centre, "Algeria Puts Draft Oil Reform Bill on Hold," web site www.worldmarketsanalysis.com (April 7, 2003).

86. Energy Information Administration, *Energy in Africa*, DOE/EIA-0633(99) (Washington, DC, December 1999).
87. Energy Information Administration, "Country Analysis Briefs: Algeria," web site www.eia.doe.gov (January 2003).
88. World Markets Research Centre, "BP Teams Up with Sonatrach in Major LNG Venture," web site www.worldmarketsanalysis.com (October 27, 2003).
89. Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003).
90. "Worldwide Look at Reserves and Production," *Oil & Gas Journal*, Vol. 101, No. 49 (December 22, 2003), pp. 46-47.
91. World Markets Research Centre, "Country Report—Nigeria (Energy)," web site www.worldmarketsanalysis.com (October 16, 2003).
92. Energy Information Administration, *The Global Liquefied Natural Gas Market: Status & Outlook*, DOE/EIA-0637(2003) (Washington, DC, December 2003).
93. Energy Information Administration, *The Global Liquefied Natural Gas Market: Status & Outlook*, DOE/EIA-0637(2003) (Washington, DC, December 2003).
94. Energy Information Administration, *The Global Liquefied Natural Gas Market: Status & Outlook*, DOE/EIA-0637(2003) (Washington, DC, December 2003).
95. World Markets Research Centre, "Middle East Gas Pipeline Project Enters Phase Two," web site www.worldmarketsanalysis.com (September 8, 2003).
96. Cedigaz, "2002 Natural Gas Statistics: Estimates of Gross and Marketed Natural Gas Production" (April 2003), web site www.cedigaz.com.
97. World Markets Research Centre, "Country Report: Angola, Energy," web site www.worldmarketsanalysis.com (October 7, 2003).
98. "Natural Gas: LNG Africa," *Platts Global Energy*, web site www.platts.com (2003).
99. Cedigaz, "2002 Natural Gas Statistics: Estimates of Gross and Marketed Natural Gas Production" (April 2003), web site www.cedigaz.com.

Coal

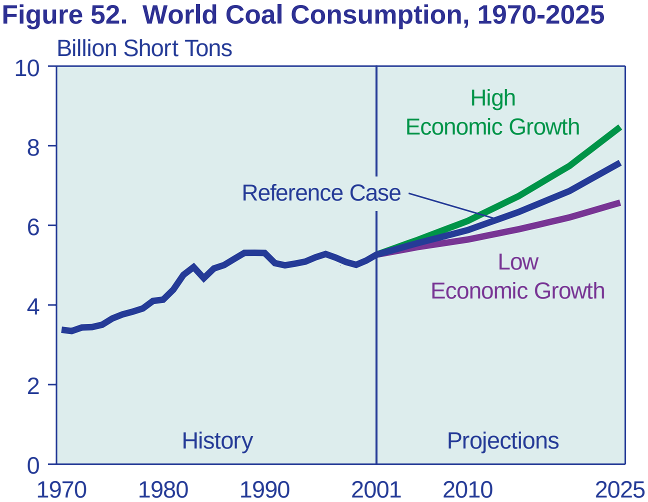
Although coal use is expected to be displaced by natural gas in some parts of the world, only a slight drop in its share of total energy consumption is projected by 2025. Coal continues to dominate fuel markets in developing Asia.

World coal consumption has been in a period of generally slow growth since the late 1980s, a trend that is projected to continue. Although total world consumption of coal in 2001, at 5.26 billion short tons,[10] was more than 27 percent higher than the total in 1980, it was 1 percent below the 1989 peak of 5.31 billion short tons (Figure 52). The *International Energy Outlook 2004* (*IEO2004*) reference case projects growth in coal use between 2001 and 2025, at an average annual rate of 1.5 percent (on a tonnage basis), but with considerable variation among regions.

Coal use is expected to increase in all regions, with the exceptions of Western Europe, Eastern Europe, and the former Soviet Union (FSU) outside Russia. In Western Europe, coal consumption declined by 30 percent between 1990 and 2001 (on a Btu basis), displaced in large part by the growing use of natural gas and, in France, nuclear power. A similar decline occurred in the countries of Eastern Europe and the former Soviet Union (EE/FSU), where coal use fell by 40 percent between 1990 and 2001, primarily as a result of the economic downturns that followed the collapse of the pro-Soviet regimes in Eastern Europe beginning in 1989 and the eventual breakup of the Soviet Union in 1991. The displacement of coal with other sources of energy, primarily natural gas, in the countries of the EE/FSU was also a contributing factor to the decline in coal use during the period. The projected slow growth in world coal use suggests that coal will account for a shrinking share of global primary energy consumption. In 2001, coal provided 24 percent of world primary energy consumption, down from 26 percent in 1990. In the *IEO2004* reference case, the coal share of total energy consumption is projected to fall to 23 percent by 2025 (Figure 53).

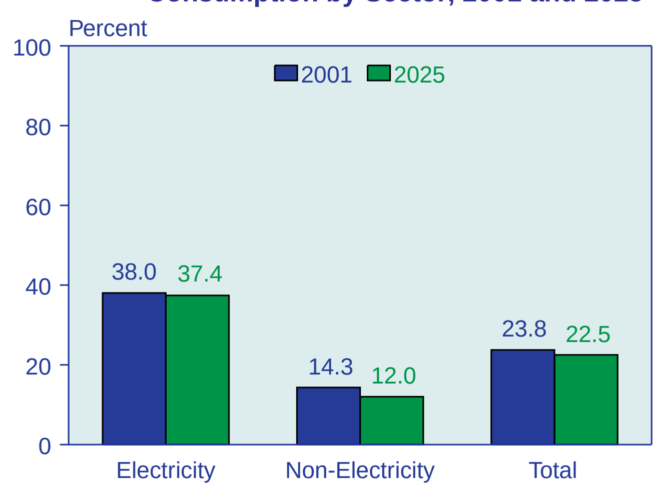
The expected decline in coal's share of energy use would be even greater were it not for large increases in energy use projected for developing Asia, where coal continues to dominate many fuel markets, especially in China and India. As very large countries in terms of both population and landmass, China and India are projected to account for 30 percent of the world's total increase in energy consumption over the forecast period. The expected increases in coal use in China and India from 2001 to 2025 account for 67 percent of the total expected increase in coal use worldwide (on a Btu basis); however, coal's share of energy use in China and India, and in developing Asia as a whole, still is projected to decline

Figure 52. World Coal Consumption, 1970-2025



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

Figure 53. Coal Share of World Energy Consumption by Sector, 2001 and 2025



Sources: **2001:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **2025:** EIA, System for the Analysis of Global Energy Markets (2004).

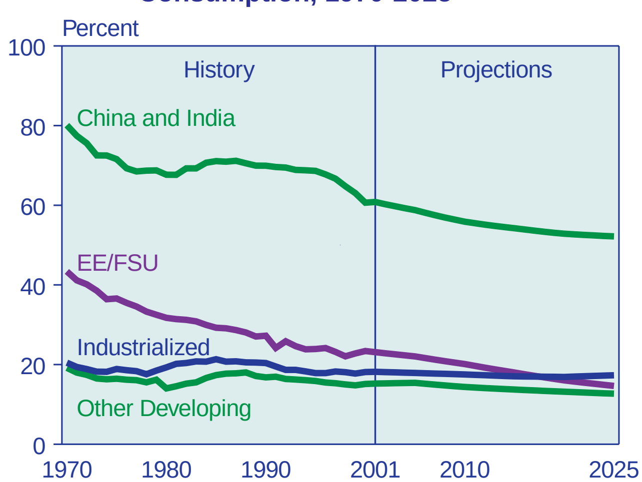
[10]Throughout this chapter, tons refers to short tons (2,000 pounds).

Figure 54). In comparison, the United States accounts for 18 percent of the increase in world energy consumption projected in *IEO2004* and 22 percent of the projected increase in world coal consumption.

Coal consumption is heavily concentrated in the electricity generation sector, although significant amounts are also used for steel production. In 2001, coal accounted for 24 percent of total world energy consumption and for 38 percent of the energy consumed worldwide for electricity production (Figure 53). Coal is also an essential input for steel production, primarily in the basic oxygen furnace process, which currently accounts for about 60 percent of world crude steel production [***1***]. Almost 64 percent of the coal consumed worldwide is used for electricity generation, and in almost every region power generation accounts for the bulk of all the projected growth in coal consumption [**2**]. Where coal is used in the industrial, residential, and commercial sectors, other energy sources—primarily natural gas—are expected to gain market share. One exception is China, where coal continues to be the main fuel in a rapidly growing industrial sector, reflecting the country's abundant coal reserves and limited access to other 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 replacement of steel by other materials in end-use applications.

The combustion of coal produces several types of emissions that adversely affect the environment. The five principal emissions associated with coal consumption in the electricity and end-use energy sectors are sulfur dioxide (SO_2), which has been linked to acid rain and increased incidence of respiratory illnesses; nitrogen oxides (NO_x), which have been linked to the formation of acid rain and photochemical smog and to depletion of the Earth's ozone layer; particulates, which have been linked to the formation of acid rain and increased incidence of respiratory illnesses; carbon dioxide (CO_2), which has been at the center of ongoing study and debate about global climate change; and mercury, which has been linked with both neurological and developmental damage in humans and other animals. Mercury concentrations in the air usually are low and of little direct concern; however, when mercury enters water—either directly or through deposition from the air—biological processes transform it into methylmercury, a highly toxic chemical that accumulates in fish and the animals (including humans) that eat fish [**3**]. (For additional discussion of SO_2, NO_x, particulates, CO_2, and mercury emissions, see the chapter on "Environmental Issues and World Energy Use.")

Figure 54. Coal Share of Regional Energy Consumption, 1970-2025



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

The *IEO2004* projections are based on current laws and regulations and do not reflect the possible future ratification of proposed policies to address environmental concerns. In particular, the forecast does not directly assume compliance with the Kyoto Protocol, which currently is not a legally binding agreement, although it does take into account the fact that some countries, such as those in Western Europe, are already taking actions to reduce greenhouse gas emissions. In effect, fuel use patterns in those countries are shifting in favor of fuels such as natural gas and renewables, which produce smaller amounts of greenhouse gas emissions per unit of energy input than do more carbon-intensive fuels, including coal and petroleum products. Similarly, regulation of mercury emissions from coal-fired power plants is not a factor in the *IEO2004* forecast, because proposed regulations in several countries, including the United States, Canada, and the European Union, are not final.

World coal trade is projected to increase from 656 million tons in 2001 to 919 million tons in 2025, accounting for between 12 and 14 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 trade. Details of recent changes in international coal markets, along with a detailed assessment regarding the long-term outlook for world coal trade, are provided at the end of this chapter.

Reserves

Total recoverable reserves of coal around the world are estimated at 1,083 billion tons[11]—enough to last

[11] 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.

approximately 210 years at current consumption levels (Figure 55). Although coal deposits are widely distributed, 60 percent of the world's recoverable reserves are located in three countries: 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 2001, these seven countries accounted for 80 percent of total world coal production [*4*].

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-grade bituminous coals that can be used to manufacture coke. Together, these three countries supplied 81 percent of the coking coal traded worldwide in 2002 (see Table 13 on page 89).

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 makes its transportation costs higher than those for bituminous coal on a Btu basis) and other problems related to transport and storage. In 2001, lignite accounted for 18 percent of total world coal production (on a tonnage basis) [*5*]. The top three producers were Germany (193 million tons), Russia (110 million tons), and the United States (84 million tons), which as a group accounted for 41 percent of the world's total lignite production in 2001.

On a Btu basis, lignite deposits show considerable variation. Estimates by the International Energy Agency, for coal produced in 2001, 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 4.55 million Btu per ton in Greece to a high of 12.25 million Btu per ton in Canada [*6*]. In comparison, bituminous coal supplied to U.S. electric utilities in 2001 had a heat content of 23.84 million Btu per ton [*7*].

Regional Consumption

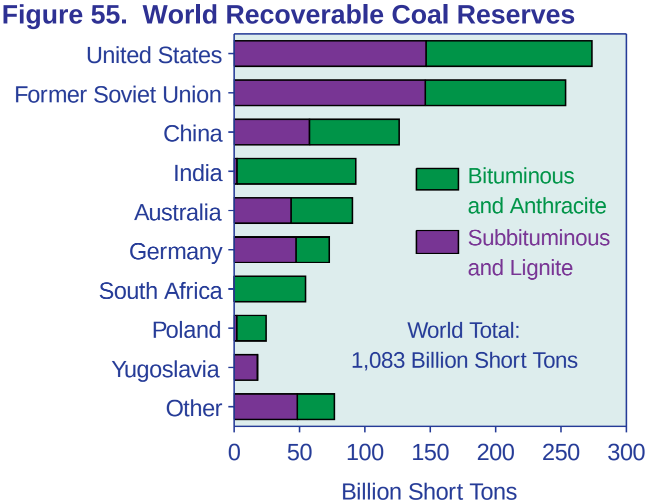
Developing Asia

The countries of developing Asia accounted for 40 percent of the world's coal consumption in 2001. Primarily as a result of substantial growth in coal consumption in China and India over the forecast period, developing Asia, taken as a whole, is projected to account for a 51-percent share of total world coal consumption by 2025.

The large increases in coal consumption projected for China and India (Figure 56) are based on an outlook for strong economic growth (6.1 percent per year in China and 5.2 percent per year in India between 2001 and 2025) and the expectation that much of the increased demand for energy will be met by coal, particularly in the industrial and electricity sectors. The *IEO2004* forecast assumes that necessary investments in the countries' mines, transportation, industrial facilities, and power plants will be made.

In China, 58 percent of the coal demand in 2001 occurred in the non-electricity sectors, for steam and direct heat

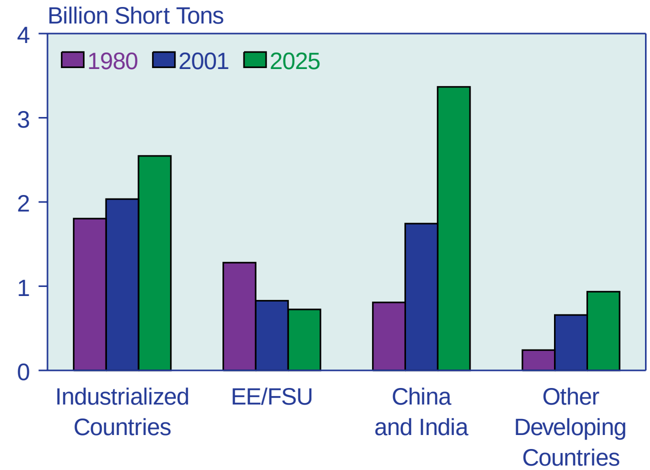
Figure 55. World Recoverable Coal Reserves



Note: Data for the U.S. represent recoverable coal estimates as of January 1, 2001. Data for other countries are as of January 1, 2000.

Source: Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), Table 8.2, web site www.eia.doe.gov/iea/.

Figure 56. World Coal Consumption by Region, 1980, 2001, and 2025



Sources: **1980 and 2001:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219 (2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **2025:** EIA, System for the Analysis of Global Energy Markets (2004).

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. Although coal demand in China's non-electricity sectors is expected to increase by 8 quadrillion Btu over the forecast period, the non-electricity share of total coal demand is projected to decline to 44 percent by 2025. In 2001, China was the world's leading producer of both steel and pig iron [*8*].

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 projected increase in oil use comes from rising demand for energy for transportation. Growth in the consumption of natural gas is expected to come primarily from increased use for space heating in the residential and commercial sectors.

With a substantial portion of the increase in China's demand for both oil and natural gas projected to be met by imports, the construction of a China's first coal liquefaction plant was recently initiated by the Shenhua Coal Liquefaction Corporation, with an expected startup in 2007 [*9*]. The facility will be located in Inner Mongolia and will be capable of converting 5.5 million tons of coal to 7.3 million barrels of petroleum products annually. By comparison, South Africa's most recently constructed coal liquefaction plant (built by SASOL at Secunda, South Africa, in 1982) is capable of producing more than 25 million barrels of coal liquids annually.

In China's electricity sector, coal use is projected to grow by 4.1 percent a year, from 10.7 quadrillion Btu in 2001 to 28.2 quadrillion Btu in 2025. In comparison, coal consumption by electricity generators in the United States is projected to rise by 1.5 percent annually, from 21.0 quadrillion Btu in 2001 to 30.3 quadrillion Btu in 2025. One of the key implications of the substantial rise in coal use for electricity generation 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 to build approximately 171 gigawatts of additional coal-fired capacity by 2025.[12] At the beginning of 2001, China had 232 gigawatts of coal-fired generating capacity [*10*].

Although China is heavily dependent on coal as a source of indigenous energy supply, a number of energy projects involving other fuels are in the pipeline and will contribute significantly to domestic energy supply. Two major projects that are well underway are the Three Gorges Dam and the West-East Gas Pipeline Project. When completed in 2009, the 18.2-gigawatt Three Gorges Dam will have 26 generating turbines and be capable of producing 84.7 billion kilowatthours of electricity annually, or about 5 percent of total electricity demand projected for China in 2010 in the *IEO2004* reference case [*11*]. The first four generating turbines at the Three Gorges Dam began operating in 2003. A major new upgrade to China's electricity grid, the West-East Power Transmission Project, will facilitate the transmission of electricity from Three Gorges to load centers in eastern and southern China.

A second major energy project is the West-East Gas Pipeline Project. The 2,500-mile-long pipeline will be capable of transporting 706 billion cubic feet of natural gas annually from China's Tarim Basin in the northwest part of the country to eastern and southern provinces [*12*]. The pipeline is scheduled to be fully operational by the beginning of 2005. Annual sales are expected to reach 420 billion cubic feet by 2009, equivalent to 22 percent of total natural gas consumption projected for China in 2010 in the *IEO2004* reference case.

In India, projected growth in coal demand occurs primarily in the electricity sector, which currently accounts for a little more than three-quarters of India's total coal consumption. Coal use for electricity generation in India is projected to rise by 2.3 percent per year, from 5.0 quadrillion Btu in 2001 to 8.6 quadrillion Btu in 2025, implying that India will need to build approximately 57 gigawatts of additional coal-fired capacity.[13] At the beginning of 2001, India's total coal-fired generating capacity amounted to 66 gigawatts [*13*].

India's state-owned National Thermal Power Corporation (NTPC) is the largest thermal power generating company in India. At present, it has 17 gigawatts of coal-fired capacity and another 3 gigawatts under construction that rely almost exclusively on India's state-owned coal producer, Coal India Limited (CIL), for its supply of coal [*14*]. Later in this decade, however, demand from the power sector is expected to outstrip CIL's production target level, with the result that NTPC and the other utilities in India will begin supplementing domestic coal supplies with additional shipments from the international market [*15*].

[12]Based on the assumption that, on average, coal consumption at China's fleet of coal-fired power plants will rise to a level of 70 trillion Btu per gigawatt by 2025. Higher average utilization rates (or capacity factors) for coal plants, taken as a whole, would increase the amount of coal consumed per unit of generating capacity, while overall improvements in conversion efficiencies would have the opposite effect. In EIA's *Annual Energy Outlook 2004* reference case forecast, U.S. coal-fired power plants are projected to consume an average of 72 trillion Btu of coal per gigawatt of generating capacity in 2025, based on a projected average utilization rate of 83 percent and an average conversion efficiency of 34.6 percent. At present, similar projections of generating capacity, capacity utilization, and conversion efficiencies are not available from EIA's System for the Analysis of Global Energy Markets (SAGE).

[13]Based on the assumption that, on average, coal consumption at India's coal-fired power plants will rise to a level of 70 trillion Btu per gigawatt by 2025. See previous footnote for discussion of the factors that affect the amount of coal consumed per unit of generating capacity.

In the other areas of developing Asia, a considerably smaller rise in coal consumption is projected over the forecast period, based on expectations for 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 South Korea) is projected to increase by 2.0 percent per year, from 3.4 quadrillion Btu in 2001 to 5.4 quadrillion Btu in 2025.

The key motivation for increasing use of coal in other developing Asia is diversity of fuel supply for electricity generation [*16*]. This objective exists even in countries that have abundant reserves of natural gas, such as Thailand, Malaysia, Indonesia, and the Philippines. In the *IEO2004* forecast, coal's share of fuel consumption for electricity generation in the region (including South Korea) is projected to decrease from 33 percent in 2001 to 27 percent in 2025.

Some of the planned additions of coal-fired generating capacity in other developing Asia for 2002 and later include 8,600 megawatts of new coal-fired capacity for South Korea by 2015, 6,900 megawatts for Taiwan by 2015, 5,600 megawatts for Malaysia by 2010, 1,346 megawatts for Thailand by 2007, and 1,320 megawatts for Indonesia by 2006 [*17*]. In addition to planned capacity additions, a number of new coal-fired units have come on line in the region in 1999, 2000, and 2001, adding a combined total of almost 13,000 megawatts of electric power supply in South Korea (3,700 megawatts), Taiwan (3,700 megawatts), Indonesia (2,450 megawatts), Malaysia (1,000 megawatts), and the Philippines (2,040 megawatts) [*18*].

Because of environmental concerns and abundant natural gas reserves, there is considerable opposition to the addition of coal-fired capacity in Southeast Asia, particularly for countries such as Thailand and the Philippines. A number of individuals and environmental groups argue that reliance on local supplies of natural gas for electricity generation is a wiser and probably a more economical choice than constructing new coal-fired power plants that will rely on imported fuel and produce more pollution than gas-fired plants [*19*].

In Thailand, strong environmental opposition to coal has prevailed over the desire for diversification of fuel supply leading to the government's cancellation of two large coal-fired generation projects [*20*]. This leaves one planned independent power producer (IPP) coal project for Thailand, the 1,434-megawatt Map Ta Phut plant being built by BLCP Power (a consortium of energy companies), whose two units are scheduled to come on line in late 2006 and early 2007 [*21*]. The Electricity Generating Authority of Thailand (the state-owned electric utility) has tentative plans to construct a 600-megawatt lignite-fired plant in northern Thailand that would be fueled by indigenous lignite [*22*].

Industrialized Asia

Industrialized Asia consists of Australia, New Zealand, and Japan. Australia is the world's leading coal exporter, and Japan is the world's leading coal importer. In 2001, Australian coal producers shipped 214 million tons of coal to international consumers and consumed another 144 million tons (both hard coal and lignite) domestically, primarily for electricity generation. Coal-fired power plants accounted for 78 percent of Australia's total electricity generation in 2001 [*23*]. Over the forecast horizon, coal use in Australia is expected to increase slightly. Australia's Queensland district has recently completed three coal-fired power projects: Callide C power plant (840 megawatts of capacity brought on line in 2001), Millmerran plant (840 megawatts of capacity brought on line in 2002), and Tarong Power plant (450 megawatts of capacity brought on line in 2003) [*24*]. In addition, Australia's Griffin Group plans to construct a 350-megawatt coal-fired plant near the existing Collie A power plant in Western Australia [*25*].

Japan, which is the third largest coal user in Asia (behind China and India) and the seventh largest globally (following China, India, the United States, Russia, Germany, and South Africa), imports nearly all the coal it consumes, much of it originating from Australia [*26*]. Currently, slightly more than one-half of the coal consumed in Japan is used by the country's steel industry (Japan is the world's second largest producer of both crude steel and pig iron, behind China) [*27*]. Coal is also used heavily in the Japanese power sector, and coal-fired plants generated 23 percent of the country's electricity supply in 2001 [*28*]. Japanese power companies plan to construct an additional 16 gigawatts of new coal-fired generating capacity between 2001 and 2010 [*29*].

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 over coal in the generation market. Coal consumption in Western Europe has fallen by 36 percent since 1990, from 894 million tons to 574 million tons in 2001. The decline was smaller on a Btu basis, at 30 percent, reflecting the fact that much of it resulted from reduced consumption of low-Btu lignite in Germany.

Over the forecast period, coal consumption in Western Europe is projected to decline by an additional 19 percent (on a Btu basis), reflecting a slower rate of decline than was seen during the previous decade. Factors contributing to further cutbacks in coal consumption include continued penetration of natural gas for electricity generation, environmental concerns, and continuing pressure on member countries of the European Union to reduce subsidies that support domestic production of hard coal (see box on page 81).

Despite a substantial decline in coal consumption since 1990, Germany continues to be the leading coal-consuming country in Western Europe, a role that it is projected to maintain over the forecast period. Coal consumption in Germany fell by 50 percent between 1990 and 2001, from 528 million tons to 265 million tons. The *IEO2004* reference case projects a more modest rate of decline in the future, to 232 million tons in 2025.

In 2001, coal-fired plants accounted for slightly more than 50 percent of Germany's total electricity output. Lignite plants accounted for 27 percent of the total and hard coal plants 24 percent [***30***]. Current plans to replace some of Germany's older lignite-fired generating capacity have been placed on hold as a result of uncertainties surrounding the development of a European strategy to allocate carbon dioxide emission allowances [***31***]. Each of the 15 member countries of the European Union is required to submit a National Allocation Plan (NAP) to the European Commission by March 31, 2004 [***32***]. In turn, the Commission plans to issue final rulings on the individual NAPs as early as summer 2004. The actions are part of an overall plan to cap emissions of the European Union countries at the total specified under the Kyoto Protocol and to create an international emissions trading market for allowances.

In the United Kingdom, coal-fired power generation is largely being displaced by generation from new natural-gas-fired combined-cycle plants. During the 1990s, new gas-fired plants in the United Kingdom benefited from declining natural gas prices and increasing conversion efficiencies [***33***]. In the *IEO2004* forecast, coal consumption in the United Kingdom is projected to decline from 71 million tons in 2001 to 49 million tons in 2025.

In Spain, coal consumption declined from 52 million tons in 1990 to 45 million tons in 2001 [***34***]. The coal share of Spain's total electricity generation is projected to decline as gas-fired plants proliferate. The owners of Spain's coal-fired generating plants, Endesa and Union Fenosa, plan to keep most of the plants in operation but acknowledge that their role is likely to shift from baseload to peaking generation.

Major projects currently underway at two of Spain's coal-fired plants will enable them to operate entirely on imported coal [***35***]. The plants, which currently burn blends of domestic lignite and imported coal, are Union Fenosa's 550-megawatt Meirama plant and Endesa's 1,400-megawatt As Pontes plant. Because the imported coal will have a higher heat content than the domestic lignite it will be replacing, the increased quantity of coal imports will be considerably less than the 9 million tons of domestic lignite currently consumed at the two plants. In 2000, the local lignite burned at the Meirama and As Pontes plants had average heat contents of approximately 6.9 and 6.6 million Btu per ton, respectively [***36***].

In France, coal consumption declined from 35 million tons in 1990 to 21 million tons in 2001. Although several coal-fired generating plants have been earmarked for retirement, the country's two main thermal generators—EDF (Électricité de France) and SNET (Société Nationale d'Électricité et de Thermique—have embarked on an investment plan to refurbish many of their existing coal plants for the purpose of extending their operating lives to at least 2015 [***37***]. While coal plants in France are typically operated as peaking capacity (the average capacity factor for France's fleet of coal-fired generating plants in 2001 was slightly under 20 percent), it is felt that coal-fired generation plays an important role in balancing out the country's nuclear-heavy generation mix [***38***]. Nuclear power plants accounted for 77 percent of total electricity generation in Frnace in 2001, with hydropower and coal adding 14 percent and 5 percent, respectively [***39***]. Nevertheless, the *IEO2004* reference case expects some additional declines in overall coal use in France, with consumption projected to fall to 11 million tons in 2025.

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 over the forecast period. The government of Denmark has stated that its goal is to eliminate coal-fired generation by 2030 [***40***]. In 2001, 47 percent of Denmark's electricity was supplied by coal-fired plants [***41***].

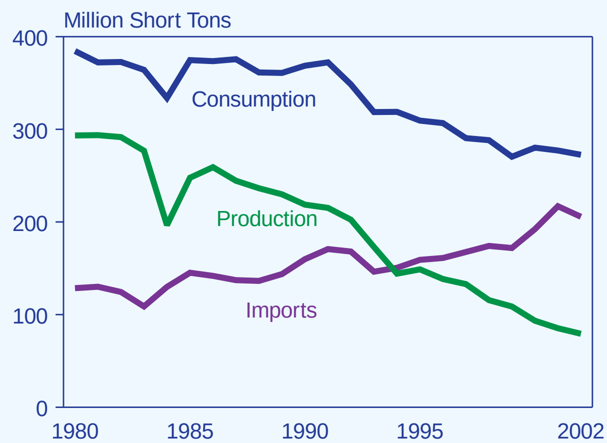
Coal consumption in Italy is projected to decline only slightly in the *IEO2004* forecast, from 22 million tons in 2001 to 20 million tons in 2025. Factors contributing to the continued use of coal in Italy over the forecast horizon include near-term plans by Enel, Italy's dominant electricity company, to switch some of its high-cost oil-fired capacity to coal, and the recent conversion of two units at Endesa Italia's Fiume Santo power station in Sardinia from Orimulsion to coal [***42***].

Partially offsetting the expected declines in coal consumption elsewhere in Europe is a projected increase in consumption of indigenous lignite for power generation in Greece. Under a burden-sharing agreement reached by the countries of the European Union in June 1998, Greece committed to capping its emissions of

Coal Production and Subsidies in Western Europe

In Western Europe, recent trends in consumption of hard coal[a] are closely correlated with trends in its production, primarily because coal imports have increased by considerably less than production has declined (see figure below). From 1980 to 2002, coal imports to Western Europe increased by 77 million tons, while hard coal production declined by 214 million tons. 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) continued to produce hard coal,[b] and all have seen their output of hard coal decline since 1990. The European Union will add two additional hard coal producers, Poland and the Czech Republic, in 2004.[c] In addition to hard coal, Germany and Greece produce and consume substantial amounts of lignite, and some lignite is also produced at two mines in the northwestern area of Spain.

Production, Consumption, and Imports of Hard Coal in Western Europe, 1980-2002



Note: Data for 2002 are preliminary.
Source: International Energy Agency, Databases for *Coal Information 2003*, web site http://data.iea.org.

The governments of Germany, Spain, France, and the United Kingdom currently support domestic production of hard coal through subsidies approved by the European Commission (see table on page 82).[d] In 2001, authorized subsidies amounted to $3,668 million in Germany, $919 million in Spain, $875 million in France, and $90 million in the United Kingdom (in nominal U.S. dollars).[e] In Germany, Spain and France, the average subsidy per ton of coal produced exceeds the average value of imported coal. Hard coal production is expected to come to an end in France in 2004, but the governments in Germany and Spain plan to continue financial support for their hard coal industries, while acknowledging that future reductions in coal production are inevitable when existing mines exhaust their minable reserves.

After 50 years in force, the European Coal and Steel Community treaty expired in July 2002. The European Commission has proposed a new state aid program for coal, establishing the continuation of subsidies for hard coal production in member states through December 31, 2010.[f] The Commission wants to establish measures that will promote the development of renewable energy sources while maintaining a minimum level of subsidized coal production in the European Union as an "indigenous primary energy base." The guiding principle will be that subsidized coal production will be limited to the minimum necessary for energy security—maintaining access to coal reserves, keeping equipment in an operational state, preserving the professional qualifications of a nucleus of coal miners, and safeguarding technological expertise.

In the United Kingdom, hard coal production fell from 104 million tons in 1990 to 35 million tons in 2001.[g] Of the 2001 total, 19 million tons was from underground operations and 16 million tons from surface mines.[h] The United Kingdom's remaining hard coal mines are by far the most productive in Western Europe, and

(continued on page 82)

[a]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.
[b]Directorate-General XVII—Energy, European Commission, *The Market for Solid Fuels in the Community in 1996 and the Outlook for 1997* (Brussels, Belgium, June 6, 1997), web site www.europa.eu.int.
[c]Commission of the European Communities, *Proposal for a Council Regulation on State Aid to the Coal Industry* (Brussels, Belgium, July 25, 2001), p. 17, web site www.europa.int.
[d]In Spain, subsidies support the production of both hard coal and subbituminous coal.
[e]Commission of the European Communities, *Report From the Commission On the Application of the Community Rules For State Aid To The Coal Industry In 2001* (Brussels, Belgium, October 4, 2002), p. 10, web site www.europa.eu.int.
[f]Commission of the European Communities, *Proposal for a Council Regulation on State Aid to the Coal Industry* (Brussels, Belgium, July 25, 2001), web site www.europa.eu.int.
[g]Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219 (2001) (Washington, DC, February 2003), Tables 2.5 and 5.4.
[h]UK Department of Trade and Industry, "Energy Statistics: Coal," Table 2.7, web site www.dti.gov.uk.

Coal Production and Subsidies in Western Europe (Continued)

improvements in mining operations in recent years have increased average labor productivity (tons produced per miner per year) from 1,272 in 1990 to 2,929 in 2001.[i] The price of coal from domestic mines is essentially at parity with the price of coal imports, and it is likely that U.K. coal production will fluctuate with changes in international coal prices.[j] When international coal prices fell between 1998 and 2000, the government reinstated coal production subsidies for 2000 through 2002 in an effort to protect the country's remaining coal operations.[k]

At 2001 production levels, recent and impending mine closures in the United Kingdom will remove approximately 6 million tons of underground coal production by the end of 2007.[l] Mines closed or scheduled for closure include Clipstone and Betws (both closed in 2003), Ricall, Stillingfleet, and Wistow (all part of the Selby Complex and to be closed in June 2004), and Ellington (to be closed in 2007).[m] A recent report by the U.K. government indicates that underground mining operations will continue to be closed as they reach the end of their geologic and economic lives, and production at most of the country's deep mines is likely to end within the next 10 years.[n] In 2003, some additional state aid was made available to a number of underground mines, based on the premise that the resulting capital investments would provide access to additional reserves of coal.[o]

Germany's hard coal production dropped from 86 million tons in 1990 to 32 million tons in 2001.[p] Currently, all of its hard coal production comes from 10 underground mines operated by Deutsche Steinkohle.[q] Recent negotiations and political decisions by the German government, the European Commission, the miners' trade union, and Deutsche Steinkohle point to the probable closure of 5 of those mines between 2006 and 2012, reducing output to an estimated 18 million tons.[r]

(continued on page 83)

Western European Coal Industry Subsidies, Production, and Import Prices, 2001

Country	Coal Industry Subsidies (Million 2001 U.S. Dollars)	Hard Coal Production (Million Tons)	Average Subsidy per Ton of Coal Produced (2001 U.S. Dollars)	Average Price per Ton of Coal Imported (2001 U.S. Dollars)
Germany	3,668	32.4	113	39
Spain	919	15.9	58	36
France	875	2.2	403	42
United Kingdom	90	34.7	3	43

Sources: **Coal Production Subsidies:** Commission of the European Communities, *State Aid Scorecard—Statistical Tables*, web site www.europa.eu.int; and U.S. Federal Reserve Bank, "Foreign Exchange Rates (Annual)," web site www.federalreserve.gov (January 6, 2004). **Production:** Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Average Price of Coal Imports:** International Energy Agency, *Coal Information 2003* (Paris, France, November 2003).

[i]International Energy Agency, *Coal Information 2003* (Paris, France, November 2003), Table 6.4.

[j]Commission of the European Communities, *Proposal for a Council Regulation on State Aid to the Coal Industry* (Brussels, Belgium, July 25, 2001), pp. 24-25, web site www.europa.eu.int.

[k]"Coal Industry Receives Additional Funds as EU Drafts New Aid Plan," *Financial Times: International Coal Report*, No. 530 (July 31, 2001), pp. 8-9.

[l]"Britain's Coal Industry," UK Coal, web site www.rjb.co.uk (accessed: February 8, 2004).

[m]UK Department of Trade and Industry, "Energy Statistics: Coal," Table 2.10, web site www.dti.gov.uk; "100 Jobs to Go as Pit Shuts," BBC News (July 23, 2003), web site news.bbc.co.uk; and "End Predicted for Lone Coal Mine," BBC News (March 27, 2003), web site news.bbc.co.uk.

[n]UK Department of Trade and Industry, *Energy White Paper: Our Energy Future—Creating a Low Carbon Economy*, Cm 5761 (February 2003), pp. 93-94.

[o]UK Department of Trade and Industry, *Energy White Paper: Our Energy Future—Creating a Low Carbon Economy*, Cm 5761 (February 2003), pp. 93-94; and "UK Coal PLC (UKC.L) Investment Aid," *Regulatory News Service* (December 18, 2003).

[p]Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), Tables 2.5 and 5.4.

[q]International Energy Agency, *Coal Information 2003* (Paris, France, November 2003), Tables 6.1; and "New German Import Surge on the Horizon," *McCloskey's Coal Report*, No 65 (July 25, 2003), p. 8.

[r]"New German Import Surge on the Horizon," *McCloskey's Coal Report*, No 65 (July 25, 2003), p. 8.

Coal Production and Subsidies in Western Europe (Continued)

Germany continues to be the world's top producer of lignite, despite substantial reductions over the past decade. Between 1990 and 2001, German lignite production fell by 55 percent, from 427 to 193 million tons, primarily because natural gas has displaced both lignite and lignite-based "town gas"[s] in the eastern states since reunification in 1990.[t] The collapse of industrial output in the eastern states was a contributing factor.

In Spain, hard coal production fell from 22 million tons in 1990 to 16 million tons in 2001.[u] Spain has adopted a restructuring plan for 1998 through 2005 that includes a gradual decline to 12 million tons of production.[v] In addition to hard coal, two lignite mines in Spain produced 9 million tons in 2001. Both mines, however, are scheduled to close in the near future.[w]

In France, production of hard coal declined from 12 million tons in 1990 to 2 million tons in 2001.[x] The closure of the country's three remaining coal mines in 2003 (Gardanne and Merlebach) and 2004 (La Houve) will bring an end to the country's 200-year history of coal production.[y]

Greece is another major producer of coal in Western Europe, but its reserves and production consist of lower-ranked lignite. Lignite production in Greece increased from 57 million tons in 1990 to 74 million tons in 2001,[z] virtually all used for electricity generation. The heat content of lignite reserves in Greece is low, even in comparison with lignite reserves in other countries, and substantial amounts are required per unit of electricity generated.

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

[t]Directorate-General XVII—Energy, European Commission, *Energy in Europe: European Union Energy Outlook to 2020* (Brussels, Belgium, November 1999), p. 47.

[u]Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219 (2001) (Washington, DC, February 2003), Tables 2.5 and 5.4.

[v]Commission of the European Communities, *Proposal for a Council Regulation on State Aid to the Coal Industry* (Brussels, Belgium, July 25, 2001), p. 25, web site www.europa.eu.int.

[w]"Spain Promises Import Bonanza," *McCloskey Coal Report, No. 19* (September 21, 2001), pp. 21-22.

[x]Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219 (2001) (Washington, DC, February 2003), Tables 2.5 and 5.4.

[y]"French Gardanne Coal Mine to be Shut, Miners Protest," *Platts Commodity News* (February 4, 2003); and R. Tieman, "France Puts an End to Its Mining Industry," *The Business* (January 12, 2003).

[z]Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), Table 5.4.

greenhouse gases by 2010 at 25 percent above their 1990 level—a target that is substantially less severe than the emissions target for the European Union as a whole, which caps emissions at 8 percent below 1990 levels by 2010 [***43***]. The European Union's burden-sharing agreement permitted higher emission targets for several member countries—including Greece, Spain, Portugal, and Ireland—primarily on the basis of economic conditions and the fact that greenhouse gas emissions for those countries are low in comparison with most of the other member countries.

Virtually all the coal produced in Greece is lignite that is used for electricity generation. In 2001, lignite-fired power plants (4,516 megawatts of capacity) accounted for 66 percent of the country's total electricity output [***44***]. A new 330-megawatt lignite-fired power plant came on line in northern Greece in mid-2003, and another unit of the same size is scheduled to be built soon at the same site [***45***].

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 40 percent, from 1,376 million tons in 1990 to 828 million tons in 2001. 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 *IEO2004* reference case, coal's share of total EE/FSU energy consumption is projected to decline from 23 percent in 2001 to 15 percent in 2025, and the natural gas share is projected to increase from 45 percent in 2001 to 52 percent in 2025.

Of the 15 FSU countries, Russia, Ukraine, and Kazakhstan together accounted for 98 percent of the region's total coal consumption and 99 percent of its coal production in 2001 [***46***]. Intraregional coal trade in the FSU has been substantial over the years, and the region as a whole is relatively self-sufficient in terms of coal supply. Coal imports from non-FSU countries in 2001 (including both seaborne and other shipments) was less than 2 million tons [***47***].

In addition to substantial declines in economic output and energy demand that followed the breakup of the Soviet Union in 1991, the transition of coal production from state-run enterprises to private companies in the three major coal-producing FSU countries has reduced their coal output. From 1990 to 2001, total energy consumption in the FSU declined by 18.8 quadrillion Btu, or 31 percent, and coal consumption fell by 5.4 quadrillion Btu, or 41 percent.

Both Kazakhstan and Russia have shown considerable progress in terms of closing uneconomical mining operations and selling government-run mining operations to the private sector, but Ukraine has made considerably less progress in its restructuring efforts. In Kazakhstan, many high-cost underground coal mines have been closed, and its more competitive surface mines are now owned and operated by international energy companies [***48***]. In Russia, the World Bank estimated that 77 percent of the country's coal production in 2001 would originate from mines not owned by the government, and that percentage was expected to increase to more than 90 percent by the end of 2002 [***49***].

Privatization of the coal industry in Ukraine faces a variety of challenges, including financial instability (many of the country's coal operations are involved in bankruptcy proceedings), lack of funds for addressing the social and environmental problems associated with mine closures, and harsh geologic conditions at many of the underground coal mines [***50***]. Geologic factors affecting Ukraine's underground mining operations include thin, steeply sloping coal seams, very deep mines, and high concentrations of methane gas. As a result, Ukraine's coal mines rank among the least productive operations in the world. In 2002, average coal mining productivity in Ukraine was approximately 320 tons per miner per year [***51***], as compared with Poland at 800 tons per miner, United Kingdom at 3,110 tons per miner, South Africa at 5,225 tons per miner, the United States at 14,110 tons per miner, and Australia at 14,220 tons per miner [***52***].

Recent data indicate a slight resurgence in coal production in the FSU region since 1998, particularly in Russia and Kazakhstan, and the governments of the three coal-producing countries have indicated that further increases in coal consumption and production are expected [***53***]. The *IEO2004* outlook for FSU coal consumption, however, is for a fairly flat trend over time. Natural gas and oil are expected to fuel most of the projected increase in the region's energy consumption.

In Eastern Europe, Poland is the largest producer and consumer of coal; in fact, it is the second largest coal producer and consumer in all of Europe, outranked only by Germany [***54***]. In 2001, coal consumption in Poland totaled 151 million tons—47 percent of Eastern Europe's total coal consumption for the year [***55***]. Poland's hard coal industry produced 113 million tons in 2001, and lignite producers added 66 million tons [***56***].

Coal consumption in other Eastern European countries is dominated by the use of low-Btu subbituminous coal and lignite produced from local reserves. The region, taken as a whole, relies heavily on local production, with seaborne imports of coal to the region totaling only 3 million tons in 2001 [***57***]. Like the FSU, Eastern Europe also experienced substantial declines in both overall energy and coal consumption during the 1990s, as national economies in the region moved from a Soviet-era emphasis on heavy industry to less energy-intensive industries. As a result, coal consumption in Eastern Europe has declined by 28 percent, from 528 million tons in 1990 to 382 million tons in 2001.

In Poland, coal is by far the most important energy source for electricity generation. Coal-fired power plants provided 93 percent of the country's total generation in 2001 [***58***]. Notwithstanding the importance of coal to Poland's economy, however, its hard coal industry faces significant challenges. Over the past several years, the Polish government has issued a number of draft plans for coal industry restructuring, aimed at moving the hard coal industry to a position of positive earnings and eliminating government subsidies. Each plan proposes the closing of a number of the country's least productive mines, which could reduce hard coal production from the 113 million tons mined in 2001 to as little as 77 million tons in 2020 [***59***]. Nevertheless, the government anticipates that coal will continue to play an important role in Poland's overall energy mix, particularly in the electricity sector, where upgrades of existing coal-fired plants are being emphasized for both environmental and efficiency reasons [***60***].

The Czech Republic, which consumed 68 million tons of coal in 2001, is the second leading coal consumer in Eastern Europe [***61***]. Coal-fired plants in the Czech Republic accounted for 70 percent of the country's total electricity generation in 2001 [***62***]. In the near term, the commissioning of the Czech Republic's second nuclear power plant, the 2,000-megawatt Temelin plant, in 2003 is expected to reduce slightly the use of coal in the country's electricity sector [***63***]. In the longer term, however, a recently approved energy policy developed by the Czech Industry Ministry calls for increased dependence on domestic supplies of energy, especially lignite [***64***].

CEZ, the Czech Republic's largest power generator, has announced that it plans to reopen an idled coal-fired power plant in Tusimice and build several new ones over the next 10 years to replace old plants in north Bohemia [***65***]. It is expected that most of the coal to fuel the plants will be produced domestically from mines in the North Bohemian region, and that the new plants will be equipped with state-of-the-art scrubbers that will help manage the pollution caused by burning lignite.

North America

Coal use in North America is dominated by U.S. consumption. In 2001, the United States consumed 1,060 million tons, accounting for 92 percent of the regional total. U.S. consumption is projected to rise to 1,567 million tons in 2025. The United States has substantial supplies of coal reserves and has come to rely heavily on coal for electricity generation, a trend that continues in the forecast. Coal provided 51 percent of total U.S. electricity generation in 2001 and is projected to provide 52 percent in 2025 [*66*].

To a large extent, the projections of increasing prices for natural gas, combined with projected 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. Increases in coal-fired generation are projected to result from both greater utilization of U.S. coal-fired generating capacity and an additional 112 gigawatts of new coal-fired capacity by 2025 (10 gigawatts of older coal-fired capacity is projected to be retired). The average utilization rate of coal-fired generating capacity is projected to rise from 69 percent in 2001 to 83 percent in 2025.

In Canada, coal consumption accounted for approximately 14 percent of total energy consumption in 2001 and is projected to decline slightly over the forecast period. In the near term, the restart of six of Canada's nuclear generating units over the next few years is expected to restrain the need for coal in eastern Canada. Between September 2003 and January 2004, three of the six units, representing 2,000 megawatts of generating capacity, were returned to service. The units returned to service included Unit 4 (500 megawatts) at Ontario Power Generation's (OPG's) Pickering A plant and Units 3 and 4 (each 750 megawatts) at Bruce Power's Bruce A plant [*67*]. OPG plans to make an announcement in early 2004 regarding a startup schedule for the three remaining 500-megawatt units at its Pickering A station [*68*]. In the *IEO2004* forecast, the three remaining Pickering A units are projected to return to service by 2006.

Ontario's Liberal Party, which was victorious in the province's parliamentary elections held on October 2, 2003, has announced its intention to shut down all of the province's 7,560 megawatts of coal-fired generating capacity by 2007 [*69*]. The decision is based primarily on the premise that the health and environmental impacts of the plants' operation are unacceptable. Currently, the government is looking to energy conservation and the construction of new gas-fired power plants to assure adequate electricity supply during the planned phaseout of coal-fired generation. In 2003, coal-fired generation accounted for approximately 23 percent of Ontario's electricity supply [*70*].

Although the shut down of OPG's 1,140-megawatt Lakeview coal-fired power plant by April 30, 2005, appears to be definite, in that the action was stipulated as part of a provincial regulation issued by the previous administration, a firm closure plan has not been established yet for OPG's four remaining coal plants [*71*]. The Lakeview plant represents 15 percent of Ontario's coal-fired generating capacity, but it typically is operated as an intermediate to peaking plant and, thus, accounted for less than 7 percent of the province's coal-fired generation in 2002.

In western Canada, increased demand for electricity is expected to result in the need for some additional coal-fired generation [*72*]. Canada's lead exporter of metallurgical grade coal, Fording, is currently in the process of building two 500-megawatt coal-fired generation units in the Province of Alberta, approximately 110 miles southeast of Calgary [*73*]. The first unit is expected to be on line at the end of 2005 and the second in 2006. Additional coal-fired capacity in Alberta is being added by joint EPCOR-TransAlta investments at TransAlta's Keephills coal facility (900 megawatts), scheduled for operation in 2005, and at EPCOR's Genesee Phase 3 project (450 megawatts), scheduled for operation in winter 2004-2005 [*74*]. In late 2003, SaskPower rebuilt its 300-megawatt coal-fired Boundary Dam Unit 6 at Estevan, extending its life by an additional 20 to 25 years. The rebuild included boiler work, turbine and generator refurbishment, and a precipitator upgrade to reduce sulfur dioxide emissions. In the process, SaskPower installed a new control system and upgraded the coal pulverizer, feedwater heaters, and related components [*75*].

Mexico consumed 15 million tons of coal in 2001. Two coal-fired generating plants, Rio Escondido and Carbon II, operated by the state-owned utility Comisión Federal de Electricidad (CFE), consume approximately 10 million tons of coal annually, most of which originates from domestic mines [*76*]. In addition, CFE has recently switched its six-unit, 2,100-megawatt Petacalco plant, located on the Pacific coast, from oil to coal. The utility estimates that the plant will require more than 5 million tons of imported coal annually. Late in 2002, CFE awarded a contract for 2.5 million tons to a supplier of Australian coal, after encountering problems with a Chinese coal supplier [*77*]. A coal import facility adjacent to the plant, with an annual throughput capacity of more than 9 million tons, serves both the power plant and a nearby integrated steel mill [*78*].

Although natural gas is expected to fuel most new generating capacity to be built in Mexico over the *IEO2004* forecast period, some new coal-fired generation is also expected. In addition, based on authorization granted by the government's energy authority in 2001, CFE is in the process of soliciting bids for the 2,100-megawatt Pacifico II coal-fired power plant in the Michoacan state and is in the early planning stages of constructing a new coal-fired plant on Mexico's Gulf Coast. The Pacifico II plant, expected to come on line by 2009, will involve three 700-megawatt units in the first stage, with two additional 700-megawatt units to be added at a later date [*79*]. If constructed, the new plants would likely use imported coal.

Africa

Africa's coal production and consumption are concentrated heavily in South Africa. In 2001, South Africa produced 250 million tons of coal, representing 97 percent of Africa's total coal production for the year. Approximately three-quarters of South Africa's coal production went to domestic markets and the remainder to exports [*80*]. Ranked third in the world in coal exports since the mid-1980s (behind Australia and the United States), South Africa moved up a notch in 1999 when its exports exceeded those from the United States, then slipped back to third in 2001 when its export total was surpassed by China's. South Africa is also the world's largest producer of coal-based synthetic liquid fuels. In 1998, about 17 percent 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 [*81*].

For Africa as a whole, coal consumption is projected to increase by 78 million tons between 2001 and 2025, primarily to meet increased demand for electricity, which is projected to increase at a rate of 2.7 percent per year. Some of the increase in coal consumption is expected outside South Africa, particularly as other countries in the region seek to develop and use domestic resources and more varied, less expensive sources of energy.

The Ministry of Energy in Kenya has begun prospecting for coal in promising basins in the hope of diversifying the fuels available to the country's power sector [*82*]. In Nigeria, several initiatives to increase the use of coal for electricity generation have been proposed, including the possible rehabilitation of the Oji River and Markurdi coal-fired power stations and tentative plans to construct a large new coal-fired power plant in southeastern Nigeria [*83*]. Also, Tanzania may move ahead with plans to construct a large coal-fired power plant. The new plant would help to improve the reliability of the country's power supply, which at present relies heavily on hydroelectric generation, and would promote increased use of the country's indigenous coal supply [*84*].

A recently completed coal project in Africa was marked by the commissioning of a fourth coal-fired unit at Morocco's Jorf Lasfar plant in 2001. With a total generating capacity of 1,356 megawatts, the plant accounts for more than one-half of Morocco's total electricity supply and is the largest independent power project in Africa and the Middle East [*85*].

Central and South America

Historically, coal has not been a major source of energy in Central and South America. In 2001, coal accounted for about 4 percent of the region's total energy consumption, and in past years its share has never exceeded 5 percent. In the electricity sector, hydroelectric power has met much of the region's electricity demand, and new power plants are now being built to use natural gas produced in the region. Natural gas is expected to fuel much of the projected increase in electricity generation over the forecast period.

Brazil, with the ninth largest steel industry worldwide in 2001, accounted for more than 65 percent of the region's coal demand (on a tonnage basis), with Colombia, Chile, Argentina, and to a lesser extent Peru accounting for much of the remainder [*86*]. The steel industry in Brazil accounts for more than 75 percent of the country's total coal consumption, relying on imports of coking coal to produce coke for use in blast furnaces [*87*].

In the forecast, Brazil accounts for most of the growth in coal consumption projected for the region, with increased use of coal expected for both steelmaking (both coking coal and coal for pulverized coal injection) and electricity production. With demand for electricity approaching the capacity of Brazil's hydroelectric plants, the government recently introduced a program aimed at increasing the share of fossil-fired electricity generation in the country, primarily promoting the construction of new natural-gas-fired capacity. The plan also includes several new coal-fired plants to be built near domestic coal deposits [*88*]. In addition, serious consideration is being given to the construction of a large coal-fired power plant at the port of Sepetiba, to be fueled by imported coal [*89*].

In November 2002, the construction of Puerto Rico's first coal-fired power plant was completed as part of a long-range plan to reduce the Commonwealth's dependence on oil for electricity generation [*90*]. The 454-megawatt circulating fluidized bed (CFB) Aurora plant, located in Guayama, will require approximately 1.5 million tons of imported coal annually [*91*]. Currently, most of the coal purchased by the Aurora plant originates from Colombia.

Middle East

Turkey accounts for more than 86 percent of the coal consumed in the Middle East. In 2001, Turkish coal consumption reached 81 million tons, most of it low-Btu (approximately 6.8 million Btu per ton), locally produced lignite [**92**]. Over the forecast period, coal consumption in Turkey (both lignite and hard coal) is projected to increase by 41 million tons, primarily to fuel additional coal-fired generating capacity. Projects currently in the construction phase include a 1,300-megawatt hard-coal-fired plant being built on the southern coast of Turkey near Iskenderun, to be fueled by imported coal, and a 1,440-megawatt lignite-fired plant (Afsin-Elbistan B plant) being built in the lignite-rich Afsin-Elbistan region in southern Turkey [**93**]. When completed between 2003 and 2005, the two plants are expected to increase Turkey's annual coal consumption by approximately 23 million tons (19 million tons of indigenous lignite and 3.5 million tons of imported bituminous coal) [**94**]. Substantial amounts of lignite are required for the Afsin-Elbistan B plant because of the extremely low heat content of the indigenous lignite feedstock, estimated at approximately 4.00 million Btu per short ton.

Israel, which consumed 11 million tons of coal in 2001, accounts for most of the remaining coal use in the Middle East. In the near term, Israel's coal consumption is projected to rise by approximately 3 million tons per year following the completion of two 575-megawatt coal-fired units at Israel Electric Corporation's Rutenberg plant in 2000 and 2001 [**95**]. Israel obtains most of its coal from South Africa, Australia, and Colombia and has, in the past, also obtained coal from the United States. Recently approved plans for an additional 1,200 megawatts of coal-fired generating capacity near the Rutenberg site in 2007 should result in another increase in consumption of approximately 3 million tons of coal per year [**96**].

Trade

Overview

The amount of coal traded in international markets is small compared with total world consumption. In 2002, world imports of coal amounted to 656 million tons (Figure 57 and Table 13), representing 13 percent of total consumption [**97**]. In 2025, coal imports worldwide are projected to total 919 million tons, accounting for a 12-percent share 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 strong growth in imports in Asia (Figure 58) and moderate growth in Western Europe. Rising production costs in the indigenous coal industries of Western Europe, combined with continuing pressure to reduce industry subsidies, have led to substantial declines in production there and significant increases in coal imports (see box on page 81). In Asia, strong growth in coal demand in Japan, South Korea, and Taiwan in recent years has contributed to a substantial rise in the region's coal imports.

In 2002 and 2003, international coal markets have undergone significant changes in both supply and demand. Although 2002 was a fairly stable year for international coal markets in terms of prices, freight rates, and demand, 2003 was marked by substantial changes in almost every facet of the market.

World coal trade reached 656 million tons in 2002, reflecting an increase of less than 1 percent over the 650 million tons recorded during 2001. The market in 2002 was characterized by a continuation of low ocean freight rates through the first half of the year and declining coal export prices through much of the year [**98**]. During the latter half of 2002, however, both freight rates and coal export prices were on the rise. Higher freight rates toward the end of 2002 were attributable primarily to increasing international demand for iron ore and coal, and higher coal export prices were primarily due to increasing coal import demand. A continuation of favorable exchange rates against the U.S. dollar continued to benefit several key exporting countries in 2002, including Australia, South Africa, and Russia [**99**].[14]

Another key highlight for 2002 was the emergence of China as a significant importer of coal. Total coal imports by China reached almost 14 million tons during 2002, which was substantially higher than the annual levels of between 2 and 4 million tons from 1980 through 2001 [**100**]. Rising domestic coal prices in 2001 persuaded a number of electricity producers located on China's southern coast to turn to imported coal, which they could purchase at lower cost than domestic coal [**101**].

Although final coal trade data for 2003 were not available as of the publication date of this report, preliminary data indicate that world coal trade rose to approximately 700 million tons for the year, an increase of more than 6 percent over 2002 [**102**]. The major highlights for the international coal market in 2003 included phenomenal increases in ocean freight rates, substantial increases in coal export prices during the final quarter of the year, a weakening U.S. dollar, a curtailment of coal exports from China in late 2003, and a sharp rise in the international price of coal coke.

[14]The exchange rate for the Australian dollar was US$0.56 in December 2002, 29 percent below its recent historical peak of US$0.80 in May 1996. The exchange rate for the South African rand was US$0.11 in December 2002, 59 percent below its recent historical peak of US$0.27 in January 1996. Between August 1998 and December 2002, the Russian ruble lost 79 percent of its value compared with the U.S. dollar.

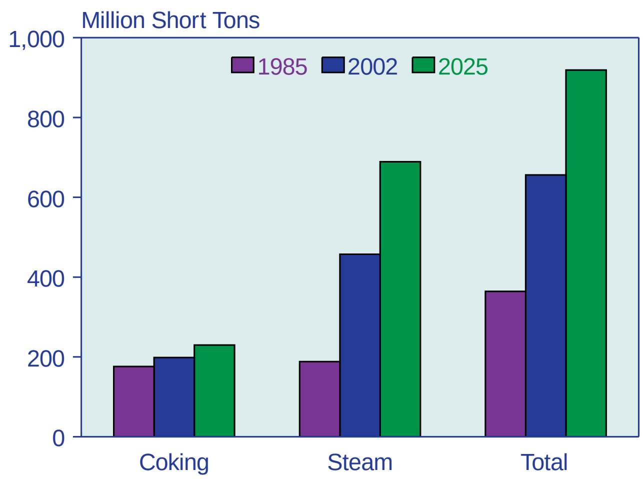
Ocean freight rates for coal rose to near all-time record highs during 2003. Much of the rise was attributable to a substantial increase in imports of iron ore by Chinese steel producers, which in turn created a shortage of ocean vessels for transporting other dry bulk products such as coal [***103***]. China's imports of iron ore in 2003 were estimated at 160 million tons, up 30 percent from 2002 [***104***]. Freight rates for major coal export routes in late 2003 were more than double the rates paid in late 2002. For example, shipments from the Richards Bay Coal Terminal in South Africa to the Rotterdam coal import terminal in the Netherlands were approximately $23.50 per ton (nominal dollars) in mid-December 2003, as compared with just over $9.00 per ton a year earlier [***105***] With projections of continuing strong growth in imports of iron ore by Chinese steel producers and little in the way of additional new shipping capacity in the pipeline, high freight rates appear to be assured for at least the next 2 to 3 years [***106***].

In addition to higher freight rates, coal importers were also hit by a substantial increase in coal export prices in 2003, adding to the delivered price of coal. The key factors underlying the higher coal export prices were increased demand for coal imports and sudden curtailments of exports from China late in the year. The free-on-board (f.o.b.) spot market price for steam coal shipped from the Richards Bay Coal Terminal in South Africa, as reported by McCloskey Coal Information Services, was $35.82 per ton in December 2003, considerably higher than the December 2002 price of $24.56 per ton [***107***]. A similar price estimate for coal originating from Newcastle, Australia, indicated an f.o.b. spot market price of $33.57 per ton in December 2003, compared with $22.52 per ton in December 2002 (all prices in U.S. dollars).

Additional information about future coal export prices is provided by the annual contract price negotiations between Japanese electric utilities and steelmakers and Australian coal producers. Price negotiations underway in late 2003 into early 2004 for Japan's 2004 fiscal year (April 1, 2004, through March 31, 2005) indicated price increases of between 20 and 25 percent for coking coal and as much as 50 percent for thermal coal [***108***]. For Japan's 2003 fiscal year, the benchmark price for coking coal was $41.91 per ton FOB port of exit (nominal dollars), and the reference price for steam coal was $24.27 per ton FOB port of exit (nominal dollars) [***109***]. For Australian coal producers, however, the expected benefits of higher prices will be attenuated due to a considerably stronger Australian currency against the U.S. dollar. In December 2003, the Australian dollar was valued at 0.74 U.S. dollar, 31 percent higher than in December 2002 [***110***].

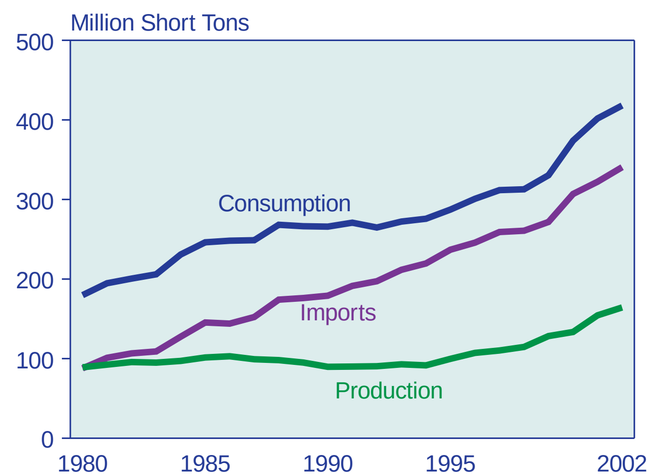
Another event affecting the world coal market in late 2003 was the sudden curtailment of coal exports from China. Although the Chinese government has taken actions to expand coal exports in recent years, the shortages of coal for the electricity generation, steel, and chemical industries, which became critical in late 2003, led to some revisions in government policies, including a reduction in tax rebates for export coal and the request that coal producers give top priority to domestic shipments over exports [***111***]. Beginning on January 1, 2004,

Figure 57. World Coal Trade, 1985, 2002, and 2025



Sources: **1985:** Energy Information Administration (EIA), *Annual Prospects for World Coal Trade 1987*, DOE/EIA-0363(87) (Washington, DC, May 1987). **2001:** SSY Consultancy and Research, Ltd., *SSY's Coal Trade Forecast*, Vol. 12, No. 3 (London, UK, June 2003); and Energy Information Administration, *Quarterly Coal Report*, October-December 2002, DOE/EIA-0121(2002/4Q) (Washington, DC, March 2003). **2025:** Energy Information Administration, National Energy Modeling System run IEO2004.D022304A (February 2004).

Figure 58. Production, Consumption, and Imports of Hard Coal in Asia, 1980-2002



Note: Data for 2002 are preliminary. Data for Australia, China, India, and New Zealand are excluded.

Source: International Energy Agency, Databases for *Coal Information 2003*, web site data.iea.org.

Table 13. World Coal Flows by Importing and Exporting Regions, Reference Case, 2002, 2010, and 2025
(Million Short Tons)

Exporters	Importers											
	Steam				Coking				Total			
	Europe[a]	Asia	America	Total[b]	Europe[a]	Asia[c]	America	Total[b]	Europe[a]	Asia	America	Total[b]
2002												
Australia	11.5	94.7	3.4	**110.1**	29.5	79.7	5.8	**115.0**	41.0	174.4	9.2	**225.0**
United States	4.2	1.6	12.9	**18.8**	12.4	0.0	8.4	**20.8**	16.6	1.6	21.3	**39.6**
South Africa	64.3	8.2	0.7	**75.0**	0.6	0.0	0.6	**1.3**	64.9	8.2	1.3	**76.3**
Former Soviet Union	20.2	10.6	0.0	**30.8**	0.6	3.1	0.0	**3.7**	20.8	13.7	0.0	**34.5**
Poland	18.4	0.0	0.0	**18.7**	2.3	0.0	0.3	**2.6**	20.7	0.0	0.3	**21.4**
Canada	0.2	2.0	1.5	**3.7**	7.3	14.9	3.6	**25.8**	7.5	16.9	5.1	**29.6**
China	2.0	72.0	3.7	**77.7**	0.3	12.7	1.7	**14.6**	2.3	84.7	5.4	**92.3**
South America[d]	29.2	0.0	18.4	**47.5**	0.0	0.0	0.0	**0.0**	29.2	0.0	18.4	**47.5**
Indonesia[e]	12.5	60.3	2.4	**75.2**	0.1	14.3	0.1	**14.6**	12.6	74.6	2.5	**89.8**
Total	**162.4**	**249.3**	**43.0**	**457.4**	**53.0**	**124.7**	**20.5**	**198.5**	**215.4**	**374.0**	**63.5**	**656.0**
2010												
Australia	8.4	121.6	0.8	**130.8**	33.3	90.4	9.7	**133.5**	41.7	211.9	10.6	**264.2**
United States	6.4	0.7	13.6	**20.7**	9.6	1.2	10.6	**21.5**	16.0	1.9	24.3	**42.2**
South Africa	75.4	3.4	4.2	**83.0**	1.1	0.5	0.0	**1.7**	76.6	3.9	4.2	**84.7**
Former Soviet Union	25.4	15.1	0.0	**40.5**	0.8	4.3	0.0	**5.1**	26.1	19.4	0.0	**45.5**
Poland	9.1	0.0	0.0	**9.1**	1.1	0.0	0.0	**1.1**	10.3	0.0	0.0	**10.3**
Canada	1.5	0.0	0.0	**1.5**	12.3	9.0	7.3	**28.6**	13.9	9.0	7.3	**30.2**
China	0.0	108.0	0.0	**108.0**	0.0	16.0	0.0	**16.0**	0.0	124.1	0.0	**124.1**
South America[d]	46.1	0.0	41.6	**87.7**	0.0	0.0	0.0	**0.0**	46.1	0.0	41.6	**87.7**
Indonesia[e]	10.2	92.7	0.0	**102.8**	0.0	12.9	0.0	**12.9**	10.2	105.6	0.0	**115.7**
Total	**182.5**	**341.5**	**60.3**	**584.3**	**58.3**	**134.3**	**27.7**	**220.3**	**240.9**	**475.7**	**87.9**	**804.6**
2025												
Australia	0.0	158.7	1.9	**160.6**	32.0	98.1	13.3	**143.4**	32.0	256.8	15.2	**304.0**
United States	0.0	0.6	11.6	**12.2**	7.3	1.4	5.5	**14.2**	7.3	2.0	17.1	**26.4**
South Africa	67.1	19.0	6.2	**92.3**	0.8	0.3	0.0	**1.1**	67.8	19.3	6.2	**93.4**
Former Soviet Union	28.7	22.0	0.0	**50.7**	0.8	5.0	0.0	**5.7**	29.4	27.0	0.0	**56.4**
Poland	4.4	0.0	0.0	**4.4**	0.6	0.0	0.0	**0.6**	5.0	0.0	0.0	**5.0**
Canada	1.5	0.0	0.0	**1.5**	8.1	9.7	9.9	**27.7**	9.7	9.7	9.9	**29.2**
China	0.0	115.8	0.0	**115.8**	5.2	16.4	2.6	**24.3**	5.2	132.1	2.6	**140.0**
South America[d]	69.1	0.0	59.4	**128.4**	0.0	0.0	0.0	**0.0**	69.1	0.0	59.4	**128.4**
Indonesia[e]	0.0	123.1	0.0	**123.1**	0.0	12.9	0.0	**12.9**	0.0	136.0	0.0	**136.0**
Total	**170.7**	**439.1**	**79.1**	**689.0**	**54.8**	**143.7**	**31.3**	**229.8**	**225.5**	**582.9**	**110.4**	**918.8**

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

[b]In 2002, total world coal flows include a balancing item used by the International Energy Agency to reconcile discrepancies between reported exports and imports. The 2002 balancing items by coal type were 2.5 million tons (steam coal), 0.3 million tons (coking coal), and 2.8 million tons (total).

[c]Includes 12.9 million tons of coal for pulverized coal injection at blast furnaces shipped to Japanese steelmakers in 2002.

[d]Coal exports from South America are projected to originate from mines in Colombia and Venezuela.

[e]In 2002, coal exports from Indonesia include shipments from other countries not modeled for the forecast period. The 2002 non-Indonesian exports by coal type were 7.4 million tons (steam coal), 1.7 million tons (coking coal), and 9.0 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: **2002:** SSY Consultancy and Research, Ltd., *SSY's Coal Trade Forecast*, Vol. 12, No. 3 (London, UK, June 2003); and Energy Information Administration, *Quarterly Coal Report*, October-December 2002, DOE/EIA-0121(2002/4Q) (Washington, DC, March 2003). **2010 and 2025:** Energy Information Administration, National Energy Modeling System run IEO2004.D022304A (February 2004).

coal export tax rebates were reduced from 13 percent to 11 percent for steam coal, from 15 percent to 5 percent for semi-soft coking coal, and from 13 percent to 5 percent for hard coking coal [***112***].

On the import side, coal buyers in countries such as Japan, South Korea, Taiwan, and the Philippines scrambled to replace tonnages originally to have been supplied from coal producers in China. For 2004, continuing shortages of coal in China's domestic market could lead to a significant reduction in coal exports. The Chinese government has indicated that coal exports in 2004 could be as much as 20 percent below the estimated 99 million tons of coal exported in 2003 [***113***].

In addition to a recent increase in international steam and coking coal prices, the cost of imported coal coke rose substantially in 2003, affecting the production costs of steelmaking in a number of countries [***114***]. China, which has emerged as a major exporter of coal coke, accounted for nearly 50 percent of the 31 million tons of coal coke traded worldwide in 2001 [***115***]. Shortages of coal coke in international markets in 2003 led to an increase in the price of Chinese coal coke from approximately $54 per ton FOB port of exit (nominal dollars) in early 2002 to nearly $218 per ton at the end of 2003 [***116***]. At a blast furnace without pulverized coal injection equipment, approximately 0.7 ton of coal coke is required to produce 1 ton of pig iron [***117***].

Major coke-importing countries include Germany, the United States, France, Turkey, India, and Brazil. Although Japanese steelmakers do not currently rely on imports of coal coke, recent events in the market have heightened their awareness that their coke-making capacity is aging and has actually declined during the past few years. In late 2003, Japanese steelmakers began considering such actions as extending the life of existing coke ovens, further reducing the use of coal coke for steelmaking, and building new coke-making capacity [***118***].

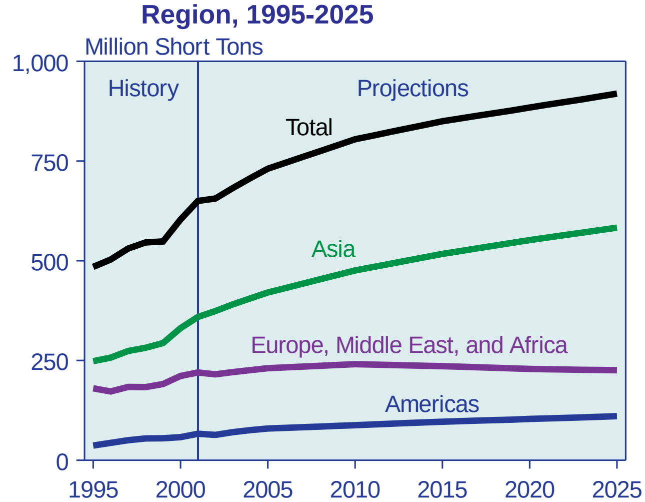
Along with strong growth in world coal trade in recent years, the geographical composition of coal supply for international markets has changed. While emerging coal exporting countries such as China, Colombia, and Indonesia have increased their output substantially over the past few years, several of the more established coal exporting countries such as the United States, South Africa, Canada, and Poland have seen their exports remain relatively constant or decline. Between 1998 and 2001, coal exports from China expanded by a remarkable 178 percent, from 36 million tons to 100 million tons [***119***]. Although its coal exports slipped to 92 million tons during 2002, China maintained its position as the second leading coal exporter in the world, ahead of Indonesia and South Africa (Table 13). The United States, which was the world's second largest coal exporter from 1984 through 1998, was surpassed by South Africa and Indonesia in 1999 and by China in 2000 [***120***].

Asia

Based primarily on strong growth in electricity demand, Asia's demand for imported coal remains poised for additional increases over the forecast period (Figure 59). 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 22 percent of total world imports in 2025, less than its 2002 share of 26 percent [***121***]. In 2002, Japan produced approximately 1 million tons of coal for domestic consumption and imported 172 million tons [***122***]. Although playing a less dominant role than in the past, Japanese industries, primarily steel mills and electric utilities, continue to exert considerable influence in the Asian coal market through their annual price negotiations with coal producers in Australia and Canada. Japan's share of total Asian coal imports has fallen from 85 percent in 1980 to 60 percent in 1990 and to 46 percent in 2002, primarily as a result of increases in coal imports by South Korea, Taiwan, Malaysia, and the Philippines [***123***].

Figure 59. Coal Imports by Major Importing Region, 1995-2025



Note: Data exclude non-seaborne shipments of coal to Europe and Asia.

Sources: **History:** SSY Consultancy and Research, Ltd., *SSY's Coal Trade Forecast*, Vol. 12, No. 3 (London, UK, June 2003); International Energy Agency, *Coal Information 2001* (Paris, France, September 2001), and previous issues; Energy Information Administration, *Quarterly Coal Report*, October-December 2002, DOE/EIA-0121(2002/4Q) (Washington, DC, March 2003), and previous issues. **Projections:** Energy Information Administration, National Energy Modeling System run IEO2004.D022304A (February 2004).

China and India, which import relatively small quantities of coal at present, are expected to account for a significant portion of the remaining increase in coal imports projected for Asia. Imports by China and India have the potential to be even higher than projected, but it is assumed in the forecast that domestic coal will be given first priority in meeting the large projected increase (1.6 billion tons) in coal demand.

Elsewhere in Asia, recent and planned additions of coal-fired capacity have increased and will continue to add to coal import demand in the region. In Malaysia, coal imports are projected to rise substantially over the forecast period to fuel new coal-fired power plants. Diversification of fuel supply for electricity generation is the key factor underlying Malaysia's plans for additional coal-fired generating capacity [***124***]. In Thailand, the 1,434-megawatt Map Ta Phut plant is scheduled to be fully operational in early 2007 [***125***]. In the Philippines, the completion of several large coal-fired power projects in recent years has lead to a substantial increase in coal imports there, from about 1 million tons in 1994 to a peak of 9 million tons in 2001 [***126***]. More recently, the Philippines is moving toward increased use of indigenous energy sources such as natural gas, hydropower, and geothermal to reduce the share of generation from import-based petroleum- and coal-fired generation [***127***].

During the 1980s, Australia became the leading coal exporter in the world, primarily by meeting increased demand for steam coal in Asia. Exports of Australian coking coal also increased, 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 34 percent in 2002, is projected to remain relatively steady over the forecast period, accounting for 33 percent in 2025 [***128***]. Australia is expected to continue as the major exporter to Asia, with its share of the region's total coal import demand projected to decline only slightly from 46 percent in 2002 to 44 percent in 2025 (Table 13).

Recently, coal from China has been displacing some Australian tonnage in several of Asia's major coal-importing countries, such as South Korea, Japan, and Taiwan [***129***]. Factors contributing to China's expanding coal export position in Asia since 1998 include recent improvements in rail and coal port infrastructure, continuing tax rebates for China's coal export industry, and the relatively short transport distances from China's coal-exporting ports to Asia's major coal-importing countries [***130***]. Over the forecast period, China is expected to maintain its current share of Asia's overall coal import market; however, the shortages of coal for China's domestic market that developed in late 2003 are expected to continue through at least 2004 and to curtail Chinese coal exports in the near term.

The United States, once a major supplier of coal to Asia, is currently only a minor participant in the Asian market. The U.S. share of Asia's coal imports declined from 28 percent in 1980 to less than 1 percent in 2002 [***131***]. Additional setbacks in U.S. coal exports to this region occurred as the result of two recent events: a reduction in coal exports from Alaska and a decision to close permanently a major coal export facility located on the U.S. West Coast.

In late 2002, Alaska's Usibelli coal mine was unable to renegotiate a long-term sales contract for coal export shipments to South Korea. In essence, other coal export suppliers, primarily Indonesian producers, were able to provide coal at a lower delivered cost to Korean electricity suppliers [***132***]. Under the contract, which dated back to 1984, the Usibelli mine typically exported between 700,000 and 800,000 tons of subbituminous coal annually to South Korea for use at the Honam coal-fired power station [***133***]. The contract was renegotiated on an annual basis, with Usibelli Coal executives hashing out the terms of the contract with their counterparts at Hyundai Merchant Marine, a Korean-based shipping company. In turn, Hyundai sold the coal to Korea East-West Power Company, Ltd. (a subsidiary of the Korea Electric Power Company). Although only partially successful, Usibelli Coal was able in September 2003 to negotiate a new 2-year contract with Hyundai Merchant Marine that specifies annual shipments of 400,000 tons of coal [***134***]. A spokesman for the Alaskan Railroad, which transports the coal from the mine to the Seward coal export terminal, described the new contract as a placeholder, enabling Alaska to remain active in the coal export market.

In early 2003, the coal export facility at the Los Angeles Export Terminal (LAXT) was permanently closed [***135***]. The decision was based on the fact that U.S. coal exports had lost their competitiveness in the Asian market that the terminal was built to serve. Consequently, the quantities of annual coal exports from LAXT were insufficient to provide a positive return to the investors who financed and operated the terminal. Although there are other coal export facilities on the West Coast, the LAXT terminal, with a capability of handling 10 million tons of coal annually, had become the primary facility for U.S. coal exports originating from mines in Utah and Colorado. The coal and petroleum coke export facilities at LAXT came on line in November 1997. Over its 5.5 years of operation, approximately 13 million tons of coal were exported from LAXT, primarily to customers in Japan [***136***]. Coal export shipments out of LAXT peaked at approximately 3.5 million tons in 2000.

Most recently, the combination of rapidly rising international coal prices and the declining value of the U.S. dollar in late 2003 led to renewed interest by foreign coal consumers in coal from the U.S. West Coast [*137*]. Unfortunately, because it is no longer possible to export large quantities of coal out of either of the Los Angeles area ports (LAXT and Long Beach), coal producers in Utah and Colorado have, in effect, been cut off from the international coal market. Other ports on the West Coast with bulk-handling terminals include the Port of Stockton near San Francisco, the Levin-Richmond Terminal in Richmond, California, and the Westshore Terminals at the Port of Vancouver. Some small shipments of coal originating from mines in Wyoming and Montana were reportedly shipped to Asian customers in early 2004 from the Westshore Terminals [*138*], despite the 1,200-mile rail haul from the mines in Wyoming and Montana to the Port of Vancouver.

Limited supplies of coking coal in the international market combined with a weakening U.S. dollar have led to some renewal of interest in Appalachian coking coal. In early 2004, Japanese steel mills reportedly booked more than 1.5 million tons of U.S. coking coal (mostly a high-volatility product) for delivery in 2004, with additional purchases for the year a distinct possibility [*139*]. U.S. coking coal exports to Asia declined from a peak of more than 24 million tons in 1982 to less than 0.5 million tons in 2001 and were virtually nonexistent in 2002 [*140*].

Although Australian coking coal producers have some new mines coming on line for export, strong demand for steel worldwide, reduced exports of coal coke from China, and the emergence of China as a major importer of coking coal are expected to keep world coking coal supplies tight in 2004 [*141*]. Some supplies of high-volatility U.S. coking coal are available for export, but higher quality, lower volatility coking coal probably will not be available from U.S. mines. In 2003, the temporary closure of PinnOak's 3.5-million-ton Pinnacle mine in West Virginia, due to a fire and methane problems, created enough of a domestic shortage of low-volatility coking coal that several U.S. coke-making facilities, and subsequently steel mills, were forced to scale back their operations temporarily [*142*]. With demand for U.S. coking coal, both domestic and for export, declining in recent years, many U.S. coking coal mines have either closed or diverted their output to the domestic steam coal market [*143*].

Europe, Middle East, and Africa

Coal imports to Europe, the Middle East, and Africa, taken as a whole, are projected to increase slightly over the forecast period, from 215 million tons in 2002 to 241 million tons in 2010, then decline to 226 million tons in 2025 (Figure 59 and Table 13). In the *IEO2004* forecast, projected declines in overall imports to the countries of Western Europe are more than offset by increases projected for Turkey, Romania, Bulgaria, and Israel.

In Western Europe, environmental pressures and competition from natural gas are expected gradually to reduce the reliance on steam coal for electricity generation, and further improvements in the steelmaking process will continue to reduce the amount of coal required for steel production. Strict environmental standards are expected to result in the closure of some of Western Europe's older coke batteries and will make it difficult to get approvals for new coke plants, thus increasing import requirements for coal coke but reducing imports of coking coal. Projected reductions in indigenous coal production in the United Kingdom, Germany, Spain, and France are not expected to be replaced by equivalent volumes of coal imports. Rather, increased use of natural gas, renewable energy, and nuclear power (primarily in France) is expected to fill much of the reduction in domestic energy supply projected to result from continuing declines in the region's indigenous coal production.

In 2002, the leading suppliers of imported coal to the region represented by the countries of Europe, the Middle East, and Africa were South Africa (30 percent), Australia (19 percent), South America (14 percent), and the former Soviet Union and Poland (each accounting for a 10-percent share). Over the forecast period, low-cost coal from South America (primarily from Colombia and Venezuela) 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.

Despite South America's current foothold and expected gains in Europe, South Africa is projected to maintain its position as the leading supplier of coal to Europe throughout most of the forecast period. Currently, plans call for a 15-million-ton expansion of South Africa's Richards Bay Coal Terminal by the end of 2006, increasing the facility's annual throughput capacity to 95 million tons [*144*].

The Americas

Compared with European and Asian coal markets, imports of coal to North and South America are relatively small, amounting to only 64 million tons in 2002 (Table 13). Canada imported 30 percent of the 2002 total, followed by the United States (27 percent) and Brazil (22 percent) [*145*]. Most (80 percent) of the imports to Brazil were coking coal, and a majority of the remaining import tonnage was steam coal used for pulverized coal injection at steel mills [*146*].

Over the *IEO2004* forecast period, coal imports to the Americas are projected to increase by 47 million tons, with most of the additional tonnage going to the United

States, Brazil, and Mexico. Coal imports to the United States are projected to increase from 17 million tons in 2002 to 46 million tons in 2025 [***147***], based on the capability and plans of existing coal-fired generating plants to import coal (primarily plants located on the eastern seaboard and in the southeastern part of the country) and announced plans to expand coal import infrastructure. Brazil and Mexico are projected to import additional quantities of coal for both electricity generation and steelmaking.

Partly offsetting the projected growth in coal imports elsewhere in the Americas, Canadian imports are expected to decline slightly over the next few years as six nuclear generating units at the Pickering and Bruce plants gradually are returned to service [***148***]. While generation from some of these units is crucial for averting expected near-term shortages in the Province's electricity supply [***149***], increasing nuclear generation over the next few years should ultimately displace some of the electricity output from Ontario's coal-fired power plants. Ontario imported 17 million tons of coal in 2002, primarily from U.S. coal mines located in Central Appalachia and the Powder River Basin [***150***].

After Ontario, Nova Scotia and New Brunswick account for most of Canada's remaining import tonnage. In 2002, Nova Scotia imported 1.9 million tons of coal and New Brunswick imported 1.2 million tons [***151***]. With the closure of the Phalen and Prince underground coal mines in 2000 and 2001, Nova Scotia Power's reliance on coal imports increased considerably in 2002. Nova Scotia Power operates four coal-fired power plants [***152***].

Historically, most of the coal imported by Canada has originated from U.S. coal mines, although South America has emerged recently as a supplier of coal to electricity producers in Nova Scotia and New Brunswick. In recent years, the importance of the Canadian market for U.S. coal exporters has increased substantially as Ontario's reliance on coal-fired generation has been stepped up to supply generation lost to reduced output from nuclear plants and as shipments of U.S. coal to overseas customers has declined. In 2002, U.S. producers exported 17 million tons of coal to Canadian consumers, corresponding to 42 percent of total U.S. exports [***153***]. As recently as 1995, U.S. coal exports to Canada, at 9 million tons, represented only 11 percent of the total amount exported [***154***].

Coking Coal

Historically, coking coal has dominated world coal trade, but its share has steadily declined, from 55 percent in 1980 to 30 percent in 2002 [***155***]. In the forecast, its share of world coal trade continues to shrink, to 25 percent in 2025. In absolute terms, despite a projected decline in imports by the industrialized countries, the total world trade in coking coal is projected to increase slightly over the forecast period as a 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 projected 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 and higher average injection rates per ton of hot metal produced. Each ton of pulverized coal (categorized as steam coal) used in steel production displaces approximately a ton of coking coal [***156***].[15] In 2001, the direct use of pulverized coal at blast furnaces accounted for 17 percent and 14 percent of the coal consumed for steelmaking in the European Union and Japan, respectively [***157***].

References

1. Web site www.worldsteel.org.
2. Energy Information Administration, System for the Analysis of Global Energy Markets (2004).
3. U.S. Environmental Protection Agency, "Fact Sheet: EPA To Regulate Mercury And Other Air Toxics Emissions From Coal- And Oil-Fired Power Plants" (Washington, DC, December 14, 2000), web site www.epa.gov.
4. Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219 (2001) (Washington, DC, February 2003), Table 2.5.
5. Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219 (2001) (Washington, DC, February 2003), Tables 2.5 and 5.4.
6. International Energy Agency, *Coal Information 2001* (Paris, France, September 2001), pp. II.21-II.23.
7. Energy Information Administration, *Annual Energy Review 2002*, DOE/EIA-0384 (2002) (Washington, DC, October 2003), Table A5.
8. Web site www.worldsteel.org.
9. "Shell Technology Will Be Used in China's Coal-to-Oil Project in Inner Mongolia," *Interfax* (March 30, 2004), web site www.interfax.com.

[15] Approximately 1.4 ton of coking coal is required to produce 1 ton of coal coke; however, according to information provided by the World Coal Institute, each ton of coal injected to the blast furnace through pulverized coal injection (PCI) equipment displaces only about 0.6 to 0.7 tons of coal coke. As a result, each ton of PCI coal displaces approximately 1 ton of coking coal. Steel companies are able to reduce their operating costs, however, because coal used for pulverized coal injection is typically less expensive than the higher quality coals required for the manufacture of coal coke.

10. DRI-WEFA, Inc., *Asia/Pacific World Energy Global Energy Market Research & Analysis 2001* (Lexington, MA, 2002), p. 75, Table 28.
11. "China's Three Gorges Generates 32 pct More Electricity Than Planned-Report," *AFX Asia* (December 30, 2003); "Three Gorges to Change China's Power Supply Patterns-Experts," *Asia Pulse* (September 16, 2003); and "Integrated National Power Grid in China to Take Shape," *Asia Pulse* (November 20, 2003).
12. "China's East-West Gas Pipeline Ready for Trial Run," *China Chemical Reporter* (September 26, 2003); and "Natural Gas Reaches East China in Trial Run of Largest Pipeline," BBC Monitoring Asia Pacific (December 18, 2003).
13. DRI-WEFA, Inc., *Asia/Pacific World Energy Global Energy Market Research & Analysis 2001* (Lexington, MA, 2001), p. 105, Table 28.
14. Web site www.ntpc.co.in.
15. "India's NTPC: Could It Become an Importer In the Future?" *International Coal Trade*, No. 1378 (April 15, 2002), p. 5.
16. "Asia Won't Yet Kick the Coal Habit," *Petroleum Intelligence Weekly* (July 9, 2001), p. 4; S. Johari, "Tenaga Seeks To Delay Two Coal-Fired Plant Projects," *Business Times* (Malaysia) (July 4, 2001), p. 4; Z. Abdullah, "TNB To Rely More on Coal," *The New Straits Times* (August 25, 2001), Section 2, p. 21; Y. Praiwan, "Plants Essential To Avoid Serious Fall in Reserves," *Bangkok Post* (September 28, 2001).
17. "Korea: 5th Long-Term Power Development Plan," *International Market Insight Reports* (February 10, 2001); "Malaysia To Raise Coal Generation Despite Gas Deposits, Says TNB Head," *Coal Week International* (January 8, 2001), p. 8; D. A. Bakar, "TNB Gives Approval for Relocation of Coal-Fired Plant," *The New Straits Times* (August 25, 2001), Section 2, p. 1; "Coal Imports To Grow as Thailand Brings on New Power Plants," *Coal Week International* (March 12, 2001), p. 5; "BLCP To Begin Work on Thai Coal Plant Next Year," *Coal Week International* (August 20, 2001), p. 3; Y. Praiwan, "Plants Essential To Avoid Serious Fall in Reserves," *Bangkok Post* (September 28, 2001).
18. "Korea: 5th Long-Term Power Development Plan," *International Market Insight Reports* (February 10, 2001); "Formosa Plastic Says Tender Filled 9 Million MT Coal Needed for 2001," *Coal Week International* (January 22, 2001), p. 8; "Taiwan's Ho-Ping Power To Start Test Runs in 1st Unit Wednesday," *Dow Jones Newswires* (July 31, 2001); "S Korea Posco to Liquidate Posenergy Unit," *Dow Jones International News* (May 27, 2001).
19. "Asia Won't Yet Kick the Coal Habit," *Petroleum Intelligence Weekly* (July 9, 2001), p. 4; N.B. Srinivasan, "Gas Versus Coal: It's No Contest," *The Bangkok Post* (October 25, 2001), p. 1; "Thai New Power Development Plan To Focus on Natural Gas," *Dow Jones Newswires* (March 15, 2001).
20. "Prime Minister Rules Out Coal for Controversial Power Plants," *Organization of Asia-Pacific News Agencies* (March 15, 2003); "Order for Coal-Fired Power Plant from BLCP Power of Thailand," *News Release—Mitsubishi Heavy Industries, Ltd* (September 19, 2003), web site www.mhi.co.jp; "EGAT Approves Construction of Two 1,400 MW Power Plants," *Thai News Service* (February 25, 2003); B. Treerapongpichit, "Banpu Unit Gets Nod for Coal-Fired Plant," *Bangkok Post* (June 26, 2002), p. 12.
21. "Order for Coal-Fired Power Plant from BLCP Power of Thailand," *News Release—Mitsubishi Heavy Industries, Ltd* (September 19, 2003), web site www.mhi.co.jp; "EGAT Approves Construction of Two 1,400 MW Power Plants," *Thai News Service* (February 25, 2003); B. Treerapongpichit, "Banpu Unit Gets Nod for Coal-Fired Plant," *Bangkok Post* (June 26, 2002), p. 12.
22. "EGAT Plans Gas and Coal Plants," *Power in Asia*, No. 387 (October 2, 2003), p. 14.
23. International Energy Agency, *Coal Information 2003* (Paris, France, November 2003), Table 3.3a.
24. "Queensland Premier Opens First of Three New Coal-Fired Stations," Coal *Week International* (July 9, 2001), p. 3.
25. "Griffin Group Will Build Coal-Fired Plant in Australia," *International Coal Trade*, No. 1383 (May 20, 2002), p. 6.
26. Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219 (2001) (Washington, DC, February 2003), Table 1.4.
27. Web site www.worldsteel.org; and International Energy Agency, *Coal Information 2001* (Paris, France, September 2001), Tables 3.9 and 3.10.
28. International Energy Agency, *Coal Information 2003* (Paris, France, November 2003), Table 3.3d.
29. H. Tagawa, Manager, Coal Fuel Department, Tokyo Electric Power Company, "Coal-Fired Power Generation in Japan and Expectations Toward U.S. Western Coal." Paper presented at the Western Coal Council's 2001 Spring Pacific Coal Forum (Park City, UT, June 4-6, 2001).
30. International Energy Agency, "Databases for the Electricity Information 2003," web site http://data.iea.org.

31. "German RWE Says It Will Replace Up to 10% of Its Power Plants From 2008," *European Daily Electricity Markets* (November 21, 2003); and "RWE Shelves Plans for New Lignite Power Plant for Now," *Dow Jones International News* (February 26, 2004).

32. "EU States Yet to Submit Any Emissions Quota Data," *Reuters News* (March 4, 2004).

33. UK Department of Trade and Industry, *Energy Paper 68: Energy projections for the UK* (London, UK: March 2000), pp. 32-44.

34. Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), Table 1.4.

35. "Spain's Fenosa Presses on With Meirama Power Plant Refit," *Platts Commodity News* (March 20, 2002); "Endesa Prepares Plant for Imports," *Platts International Coal Report*, No. 606 (March 31, 2003), p. 11; and "Endesa to Invest Euro 274 Million to Transform As Pontes 1,400 MW Coal Power Plant and Extend 20 Years Its Useful Life," *ENDESA Press Release* (March 26, 2003), web site www.endesa.com.

36. N. Ballisoy and H. W. Schiffer, RWE Rheinbraun, *Lignite in Europe, Edition 2001* (September 2001), pp. 15-16.

37. "Coal-Fired Competition Hots up in France; Endesa's Overpayment in SNET May Have Let Others Into the French Coal Picture," *Power in Europe*, No. 411 (October 13, 2003), p. 8.

38. International Energy Agency, *Coal Information 2003* (Paris, France, November 2003), Tables 3.2 and 3.3b; and "Coal-Fired Competition Hots up in France; Endesa's Overpayment in SNET May Have Let Others Into the French Coal Picture," *Power in Europe*, No. 411 (October 13, 2003), p. 8.

39. International Energy Agency, *Coal Information 2003* (Paris, France, November 2003), Table 3.3b.

40. E. Ewart and R. Marston, "Marketwatch: World Coal Trade and the Impact of Global Environmental Regulation," *Coal Age* (September 1, 2001).

41. International Energy Agency, *Coal Information 2002* (Paris, France, September 2002), Table 3.3a.

42. "Enel to Switch From Oil to Coal," *McCloskey Coal Report, No. 42* (August 23, 2002), p. 1; "Enel's CEO Wants More Coal," *International Coal Trade, No. 1397* (August 26, 2002), p. 8; "Endesa Continues Fiume Santo Conversion," *McCloskey Coal Report, No. 69* (September 19, 2003), p. 18; and "Fiume Santo Fires Up Early," *McCloskey Coal Report, No. 71* (October 17, 2003), p. 24.

43. United Nations Framework Convention on Climate Change, Report of the Conference of Parties on Its Third Session, Held at Kyoto from 1 to 10 December 1997, Kyoto Protocol to the United Nations Framework Convention on Climate Change, FCCC/CP/1997/L.7/ Add.1 (December 10, 1997), web site www.unfccc.de.

44. International Energy Agency, "Databases for the Electricity Information 2003," web site http://data.iea.org.

45. "Kapros: Greek Pool to Boost IPPs," *Power in Europe*, No. 413 (November 10, 2003), p. 4; and "A New Power Plant is to Begin Operations in the North, Near Florina," *Athens News Agency* (July 29, 2003).

46. Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), Table 2.5.

47. SSY Consultancy and Research Ltd, *SSY's Coal Trade Forecast*, Vol. 12, No. 4 (September 2003).

48. J. Chadwick, "CIS Coal," *The Mining Journal* (June 1998); PlanEcon, Inc., *Energy Outlook for Eastern Europe and the Former Soviet Republics* (Washington, DC, October 1999), pp. 13-14.

49. I. Artimiev and M. Haney, *The Privatization of the Russian Coal Industry: Policies and Processes in the Transformation of a Major Industry*, World Bank Working Paper 2820 (Washington, DC, April 2002), web site www.worldbank.org; "World Bank Approves Coal-Privatization Loan to Russia," *BBC Monitoring Former Soviet Union—Economic* (November 23, 2001).

50. "'Reform Or Perish' Message to Coal Operators," *McCloskey Coal Report*, No. 56 (March 21, 2003), p. 11; "Ukraine—An Industry Defying Reality," *McCloskey Coal Report*, No. 58 (April 18, 2003), p. 13.

51. "Ukraine—An Industry Defying Reality," *McCloskey Coal Report*, No. 58 (April 18, 2003), p. 13.

52. International Energy Agency, *Coal Information 2003* (Paris, France, November 2003), Table 6.4.

53. "Country Report: Russia (Energy)," *World Markets Analysis Online*, web site www.worldmarketsanalysis.com (February 24, 2004); "Country Report: Kazakhstan (Energy)," *World Markets Analysis Online*, web site www.worldmarketsanalysis.com (February 25, 2004); and "Country Report: Ukraine (Energy)," *World Markets Analysis Online*, web site www.worldmarketsanalysis.com (January 15, 2004).

54. Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), Tables 1.4 and 2.5.

55. Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), Table 1.4.

56. Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), Tables 2.5 and 5.4.

57. SSY Consultancy and Research, Ltd., *SSY's Coal Trade Forecast*, Vol. 12, No. 4 (September 2003).

58. International Energy Agency, "Databases for the Electricity Information 2003," web site http://data.iea.org.

59. "Polish Exports Threatened by Closures," *McCloskey Coal Report*, No. 68 (September 5, 2003), pp. 1-4; "World Bank Won't Lend Poland $300 Million, Says Restructuring Too Slow," *International Coal Report*, No. 640 (November 24, 2003), p. 7; "Polish Expert Group Reportedly Backs Closing of 12 out of 33 Total Coal Mines by 2020," *Interfax Poland Business News Service* (May 7, 2003); "New Polish Coal-Overhaul Plan Would Involve Pln 14 Bln in Debt Restructuring, Lay Offs of 28,000," *Interfax Poland Weekly Business Report* (August 11, 2003); and "Poland Threatens Unions With a Withdrawal of Coal Subsidies," *Platts International Coal Report*, No. 618 (June 23, 2003), p. 8.

60. "Poland: Energy and Electricity Forecast," *Economist Intelligence Unit: Executive Briefing*, No. 310 (January 13, 2004), p. 4.

61. Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), Table 1.4.

62. International Energy Agency, "Databases for the Electricity Information 2003," web site http://data.iea.org.

63. "Czech Republic Industry: Too Little, Too Late for Coal Mines," *Economist Intelligence Unit: ViewsWire*, No. 301 (June 25, 2003); and "CEZ Sees Electricity Output Rise 13% in 2003 to All-Time High," *Interfax Czech Republic & Slovakia Weekly Business Report* (February 6, 2004); and "Finns Push on With Europe's First Nuke in Decade," *Energy Compass* (December 18, 2003).

64. "Government Approves Country's Long-Term Energy Policy," *Interfax Czech Republic Business News Service* (March 10, 2004); and "CEA Embraces State Energy Expansion Plan But Is in No Rush To Build N-Plant," *European Spot Gas Markets* (March 11, 2004).

65. "Czech Republic Will Add New Coal-Fired Capability," *Coal Americas*, No. 15 (April 21, 2003), p. 8; "Czech Republic To Rebuild Coal-Fired Power Plants," *Coal Americas*, No. 17 (May 19, 2003), p. 17.

66. Energy Information Administration, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table A8.

67. "Bruce Nuclear Back Online After Months of Delays in Time for Cold Snap," *The Canadian Press* (January 9, 2004); "Bruce unit 3 resumes electricity production; Lengthy retrofit adds 6-8 years to reactor's life Province not 'out of the woods,' Energy Probe says," *The Toronto Star* (January 10, 2004), p. D5; and "OPG Officers Ousted; Coal Could Get Boost," *Platts Coal Outlook*, Vol. 27, No. 49 (December 8, 2003), p. 1.

68. "Nuclear Fallout," The Toronto Star (September 27, 2003), p. D1.

69. "Ontario Liberal Leader Threatens to Shut Coal Plants by 2007," *Platts International Coal Report*, No. 635 (October 20, 2003), p. 9.

70. Canada's Electricity Conservation and Supply Task Force, *Tough Choices: Addressing Ontario's Power Needs, Final Report to the Minister* (January 2004), Figure 2.F, web site www.energy.gov.on.ca.

71. A. Lindgren, "Liberals Begin to Phase Out Coal Plants," *CanWest News Service* (January 21, 2004); and Ontario Power Generation Inc., *Annual Information Form for the Year Ended December 31, 2002* (March 31, 2003), web site www.opg.com.

72. "Ontario's IMO Forecasts Province's Electricity Supply Secure for Next 10 Years," *Foster Electric Report* (September 5, 2001); M. Mittelstaedt, "New Life for Old Reactors Fans Fears for Safety," *The* Globe and Mail (May 28, 2001), p. A1; Energy Information Administration, *Nuclear Power Generation and Fuel Cycle Report 1997*, DOE/EIA-0436 (97) (Washington, DC, September 1997), Table D1.

73. "Brooks Power Project Makes It Official With Alberta Govt," *International Coal Trade*, No. 1350 (October 1, 2001), p. 10; "Fording Inc. Lays Groundwork for Coal-Fired Units in Alberta," *Coal Week International* (October 1, 2001), p. 4.

74. "TransAlta Receives Green Light For Plant Expansion," *International Coal Trade*, No. 1370 (February 18, 2002), p. 7; S. Thomas, "TransAlta Buys Half Of EPCOR Genesee Phase 3 Proj," *Dow Jones Newswires* (January 13, 2003).

75. "SaskPower To Rebuild Coal-Fired Plant," *Coal Americas*, No. 1 (October 7, 2002), p. 15; "McCloskey's News Round-up," *McCloskey Coal Report*, No. 45 (October 4, 2002), p. 25; SaskPower, "Upgrades at Boundary Dam Power Station Worth $80 Million," News Release (Regina, Saskatchewan, Canada, October 1, 2002), web site www.saskpower.com.

76. F.G. Jáuregui D., "Steam Coal Requirements of CFE." Paper presented at the Western Coal Council's Pacific Coal Forum (Park City, UT, June 23-26, 1997).

77. R. Brindal, "Xstrata Coal Australia Wins US$75M Mexico Supply Contract," *Dow Jones Newswires* (December 4, 2002).

78. "International Market Report," *King's International Coal Trade*, No. 1194 (September 11, 1998), pp. 2-3.

79. “Another Coal-Fired Power Plant Is On the Drawing Board In Mexico,” *Coal Americas*, No. 19 (June 16, 2003), p. 18; A. Harrup, “Mexico’s State Utility Plans New Coal-Fired Power Plant,” *Dow Jones Newswires* (July 3, 2001).

80. International Energy Agency, *Coal Information 2001* (Paris, France, September 2001), pp. III.37-III.38.

81. International Energy Agency, *Coal Information 2001* (Paris, France, September 2001), pp. III.36; Energy Information Administration, “Country Analysis Brief: South Africa,” web site www.eia.doe.gov (December 2000).

82. “Kenya: Energy Ministry Sets Aside Money for Coal Prospecting,” *BBC Monitoring Africa—Political* (November 20, 2000).

83. C. Akunna, “Ezeife Urges Igbo To Produce Coal-Fired Electricity,” *Africa News Service* (December 14, 2001); K.U. Kalu, “Future of Coal Industry,” *Africa* News Service (October 5, 2001); E. Imisim, “Government Gets $100m World Bank Credit for NEPA Reforms,” *Africa News Service* (August 2, 2001).

84. “Tanzania: Government Plans To Develop Coal-Fired Power Station,” *BBC Monitoring Africa—Political* (September 7, 2000).

85. “Largest IPP in Africa, Middle East Is Completed,” *Power*, Vol. 145, No. 5 (September/October 2001), p. 16.

86. Web site www.worldsteel.org.

87. International Energy Agency, *Coal Information 2001* (Paris, France, September 2001), pp. I.88 and I.97; AME Research, web site www.ame.com.au.

88. “Tractabel’s Gerasul Advances 350-MW Jacui; Will Boost Capital by $65-Million,” *Global Power Report* (July 20, 2001), p. 12; D. Clifford, “Brazil—A Modern Mining Giant,” *Mining Magazine* (July 1, 2001), p. 6.

89. “Brazil’s Inepar To Exit Distributor’s Celpa, Cemat, and Maybe Generation,” *Electric Utility Week* (May 7, 2001), p. 21.

90. “AES 454MW Guayama Project Starts Commercial Operations,” *Dow Jones Newswires* (December 2, 2002).

91. “AES Looks for 3-Year Supply,” *McCloskey Coal Report*, No. 19 (October 4, 2001), p. 18; B.K. Schimmoller, “Fuel and Materials Handling: Moving It Without Losing It,” *Power Engineering* (March 1, 2001), pp. 44-48.

92. Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219 (2001) (Washington, DC, February 2003), Tables 2.5 and 5.4; International Energy Agency, *Coal Information 2001* (Paris, France, September 2001), p. II.23.

93. U.S. Department of Energy, Office of Fossil Energy, Energy Overview of Turkey, web site www.fe.doe.gov (accessed January 21, 2004); IEA Coal Research, CoalPower 4 Database (October 2001); “Steag Markets New Coal Station Design,” McCloskey’s Coal Report, No 73 (November 14, 2003), pp. 16-17; and S. Atalay, “Turkish Govt Signs $1.62 Bln Loan for 1400MW Power Project,” *Dow Jones Newswires* (October 15, 1999).

94. M. Ersoy, Turkish Coal Enterprises, “Current Status of Turkish Lignite Sector,” presentation at the United Nation’s Economic Commission for Europe (UNECE) Ad Hoc Meeting of Experts on Coal in Sustainable Development, Geneva, Switzerland (November 17-18, 2003), web site ; “EUAS Modifies Afsin-Elbistan B Lignite Project,” *IBS Research & Consultancy Energy Line* (December 2, 2002) web site www.ibsresearch.com; and “Steag Opens 1,210 MW Coal Plant in Turkey,” *European Daily Electricity Markets* (November 24, 2003).

95. “New Plant On Line,” *Coal Week International* (February 26, 2001), p. 9; “Israel Looking to Asia, U.S., To Meet Growing Steam Coal Need,” *Coal Week International* (November 13, 2000), p. 4.

96. “1,200-MW Ashkelon Plant On Line in 2007,” *International Coal Report*, No. 594 (January 6, 2003), pp. 1,6; T. Muscal, “Gov’t Okays New Coal Power Plant,” *The Jerusalem Post* (December 30, 2002).

97. International Energy Agency, *Coal Information 2003* (Paris, France, November 2003), Tables 3.1b and 3.1c.

98. *Monthly Shipping Review SSY* (December 6, 2002), p. 5; “Coal Price Lows,” Monthly *Shipping Review SSY* (August 12, 2002), p. 4; “2002—The Year of the Bear,” *Platts International Coal Report*, No. 594 (January 6, 2003), pp. 2-3; A. Roberts, “Price Volatility Persists,” *Petroleum Economist* (October 2, 2002).

99. U.S. Federal Reserve Bank, “Foreign Exchange Rates (Monthly),” web site www.federalreserve.gov; International Monetary Fund, *International Financial Statistics Yearbook* (Washington, DC, various issues).

100. SSY Consultancy and Research Ltd, *SSY’s Coal Trade Forecast*, Vol. 12, No. 4 (London, United Kingdom, September 2003); and International Energy Agency, *Databases for the Coal Information 2003*, web site data.iea.org.

101. “Chinese 2002 Thermal Imports Likely to Reach 10 Million mt,” *Platts International Coal Report*, No. 593 (December 23, 2002), p. 3.

102. “Seaborne Coal Trade Matrix,” *Monthly Shipping Review SSY* (December 15, 2003), p. 5; and Bureau of the Census, U.S. Department of Commerce, “Monthly Report EM 522."

103. "Ocean Freight Rates Continue to Soar, Little Relief in Sight," *Coal Americas, Energy Publishing LLC*, No. 29 (November 3, 2003), p. 1.

104. "Steel/Iron Ore: Iron Ore Imports, Iron Ore Exports and Steel Production," *Monthly Shipping Review SSY* (December 15, 2003), p. 7.

105. "Freights Set in for the Long Run," *McCloskey's Coal Report*, No. 75 (December 12, 2003), pp. 20-21.

106. "Freights Set in for the Long Run," *McCloskey's Coal Report*, No. 75 (December 12, 2003), pp. 20-21.

107. "McCloskey Coal Information Services (MCIS) Key Physical Prices," *McCloskey's Coal Report*, No. 75 (December 12, 2003), p. 1; and "McCloskey Coal Information Services (MCIS) Key Physical Prices," *McCloskey's Coal Report*, No. 77 (January 23, 2004), p. 1.

108. J. Chessell, "Coalminers Sitting Pretty in Price Talks," *The Sydney Morning Herald* (January 21, 2004); and N. Todd, "Slow Burn for Thermal Coal Talks," *Herald Sun* (January 22, 2004).

109. International Energy Agency, *Coal Information 2003* (Paris, France, November 2003), Tables 2.6 and 2.11.

110. U.S. Federal Reserve Bank, "Foreign Exchange Rates (Monthly)," web site www.federalreserve.gov.

111. "Coal Exports Decrease in Year 2004," *China Coal Newsletter*, AAA Minerals International, Vol. 1, No. 2 (January 20, 2004); X. Yie, "Coal Exports Decrease to Satisfy High Domestic Demand," *China Daily* (January 5, 2004); and "China's Output Growth Seen Slowing in 2004 Despite Soaring Demand," *AFX Asia* (December 29, 2003).

112. "Coal Export Tax is Reduced in 2004," *China Coal Newsletter*, AAA Minerals International, Vol. 1, No. 1 (January 5, 2004).

113. "Coal Exports Decrease in Year 2004," *China Coal Newsletter*, AAA Minerals International, Vol. 1, No. 2 (January 20, 2004); and "Beijing to Regulate Prices," *McCloskey's Coal Report*, No. 75 (December 12, 2003), p. 18.

114. "Met Coke Prices Soar as High as the Sky," *Coal Americas, Energy Publishing LLC*, No. 30 (November 17, 2003), p. 10.

115. International Energy Agency, *Databases for the Coal Information 2003*, web site data.iea.org.

116. "Japanese Discuss New Coke Ovens as Demand Increases, Ovens Age," *Platts International Coal Report*, No. 634 (October 13, 2003), p. 9; and "Hill's Met Coke Price Indicator," *Coal Americas, Energy Publishing LLC*, No. 35 (January 26, 2004), p. 1; and "Chinese Coke Licenses for 2.3 Million mt Issued, Buyers Disappointed," *Platts International Coal Report*, No. 646 (January 12, 2004), p. 9.

117. World Coal Institute, "Coal in the Steel Industry," in *Coal: Power for Progress, Fourth Edition*, web site www.wci-coal.com (March 2000).

118. "Japanese Discuss New Coke Ovens as Demand Increases, Ovens Age," *Platts International Coal Report*, No. 634 (October 13, 2003), p. 9.

119. SSY Consultancy and Research Ltd, *SSY's Coal Trade Forecast*, Vol. 12, No. 4 (London, United Kingdom, September 2003).

120. SSY Consultancy and Research Ltd, *SSY's Coal Trade Forecast*, Vol. 12, No. 4 (London, United Kingdom, September 2003); and Energy Information Administration, *Annual Energy Review 2002*, DOE/EIA-0384(2002) (Washington, DC, October 2003), Table 7.4.

121. SSY Consultancy and Research Ltd, *SSY's Coal Trade Forecast*, Vol. 12, No. 4 (London, United Kingdom, September 2003); Energy Information Administration, National Energy Modeling System run IEO2004.D022304A.

122. International Energy Agency, *Coal Information 2003* (Paris, France, November 2003), p. I.191; and SSY Consultancy and Research Ltd, *SSY's Coal Trade Forecast*, Vol. 12, No. 4 (London, United Kingdom, September 2003).

123. SSY Consultancy and Research Ltd, *SSY's Coal Trade Forecast*, Vol. 12, No. 4 (London, United Kingdom, September 2003.

124. "Malaysian Coal Project Advances," *Power in Asia* (June 12, 2003), p. 4; "TNB to Set Ceiling on Coal Prices," *Coal Americas, Energy Publishing LLC*, No. 16 (May 5, 2003), p. 20.

125. "Order for Coal-Fired Power Plant from BLCP Power of Thailand," *News Release—Mitsubishi Heavy Industries, Ltd* (September 19, 2003), web site www.mhi.co.jp; "EGAT Approves Construction of Two 1,400 MW Power Plants," *Thai News Service* (February 25, 2003); B. Treerapongpichit, "Banpu Unit Gets Nod for Coal-Fired Plant," *Bangkok Post* (June 26, 2002), p. 12.

126. SSY Consultancy and Research Ltd, *SSY's Coal Trade Forecast*, Vol. 12, No. 4 (London, United Kingdom, September 2003).

127. "Gas-Fired Power Generation Up at 11% in Philippines Energy Mix," *Platts Commodity News* (December 15, 2003); "Philippines Power Cost in Control Despite Oil Price Rise," *Platts Commodity News* (September 26, 2002); and "Philippines to Slash Oil Use for Power to 7% by End-2002," *Platts Commodity News* (August 6, 2002).

128. Energy Information Administration, *Annual Prospects for World Coal Trade 1991*, DOE/EIA-0363 (91) (Washington, DC, June 1991), Table 1.

129. "Negative Influence From Tonne-Miles," *Monthly Shipping Review SSY* (September 10, 2001), p. 4.

130. S. Wyatt, "China Stakes Claim As Asia's Coal King," *Australian Financial Review* (May 16, 2001), p. 22; "China Rampant," *Monthly Shipping Review*, Vol. 554 (June 8, 2001), p. 4; "Increased Competition Forecast by ABARE," *Coal Week International* (June 25, 2001), p. 6.

131. SSY Consultancy and Research Ltd, *SSY's Coal Trade Forecast*, Vol. 12, No. 4 (London, United Kingdom, September 2003).

132. J. MacPherson, "Mine, Railroad Workers Hurt by End of Coal Shipments," *Alaska Journal of Commerce*, Vol. 26, No. 37 (September 15, 2002), p. 8; "Alaskan Plans Move Slowly," *International Coal Report* (September 30, 1996); and Korea East-West Power Co., Ltd., web site www.kewp.com.

133. Bureau of the Census, U.S. Department of Commerce, "Monthly Report EM 522."

134. "Usibelli to Send Coal to Korea," *Fairbanks Daily News-Miner* (September 18, 2003); and P. Dobbyn, "Contract Means Healy Coal in Korea," *Anchorage Daily News* (September 18, 2003).

135. "After Only Six Years of Operation, LAXT Shuts Its Gates," *Platts Coal Outlook*, Vol. 27, No. 20 (May 19, 2003), pp. 1 and 11.

136. "Western Export Market Revival a Shock," Coal Transportation Report (February 16, 2004), pp. 4-5; J. Gellici, "Coal Ports Struggle to Gain Advantage," Dry Cargo International, No. 5 (June 1999), pp. 42-46; and Bureau of the Census, U.S. Department of Commerce, "Monthly Report EM 522."

137. "Eastern Coal Burners Turn to Colorado/Utah for Tons: Prices Soar," *Platts Coal Outlook*, Vol. 27, No. 51 (December 22, 2003), p. 1.

138. "Western Export Market Revival a Shock," *Coal Transportation Report* (February 16, 2004), pp. 4-5.

139. "U.S. Met Coal Reenters the Japanese Market in a Big Way," *Coal Americas*, No. 35 (January 26, 2004), pp 1 and 3; and "U.S. Returns to Japan," *McCloskey's Coal Report*, No. 77 (January 23, 2004), p. 1.

140. Bureau of the Census, U.S. Department of Commerce, "Monthly Report EM 522."

141. "U.S. Coking Coal Breaks $70 Barrier," *McCloskey's Coal Report*, No. 75 (December 12, 2003), pp. 10-14; and "Met Coal: Get it While You Can at Higher Prices," Coal Americas, No. 31 (December 1, 2003), pp. 1, 4.

142. "Pinnacle workers may not be able to return until February," *Platts Coal Outlook*, Vol. 27, No. 51 (December 22, 2003), p. 7; and C. Davis, "Rise in Global Steel Demand May Impact Coke Shortage," Pittsburgh Business Times (January 26, 2004), web site www.bizjournals.com.

143. "Coking Coal Market Seeks Reunification With Once-Forgotten Partner," *Platts Coal Outlook*, Vol. 27, No. 43 (October 27, 2003), pp. 1 and 15-16; and "Will U.S. Met Exporters in Central Appalachia Continue to Feel the Squeeze," *Coal Americas*, No. 19 (June 16, 2003), pp. 8-9.

144. "Agreement Clears Way for Richards Bay Coal Terminal's R1.75bn Expansion," *The Business Report* (January 14, 2004), web site .

145. K. Stone, Natural Resources Canada, *Canadian Minerals Yearbook, 2002: Coal* (Ottawa, Canada, November 2003), web site www.nrcan.gc.ca; SSY Consultancy and Research Ltd, *SSY's Coal Trade Forecast*, Vol. 12, No. 4 (London, United Kingdom, September 2003); Energy Information Administration, *Quarterly Coal Report, October-December 2002*, DOE/EIA-0121 (2002/4Q) (Washington, DC, March 2003).

146. SSY Consultancy and Research Ltd, *SSY's Coal Trade Forecast*, Vol. 12, No. 4 (London, United Kingdom, September 2003); "Brazilian Steel Mills Look to China to Boost Coking Coal Supplies," *Platts International Coal Report*, No. 547 (February 4, 2002), p. 11.

147. Energy Information Administration, National Energy Modeling System run IEO2004.D022304A.

148. S. Brissette, "Bruce Power Begins Refueling Unit 4," *Bruce Power* (January 15, 2003), web site www.brucepower.com; C. Perkel, "Bruce Power Wins Key Approval to Refuel Two Nuclear Reactors," *The Canadian Press* (January 14, 2003); "Ontario on Track to Return Four Pickering Nukes," *Reuters News* (September 13, 2002).

149. J. Spears, "Power Problems Loom, Agency Warns," *The Toronto Star* (December 24, 2002), web site www.thestar.com.

150. Energy Information Administration, *Quarterly Coal Report, October-December 2002*, DOE/EIA-0121 (2002/4Q) (Washington, DC, March 2003), Table 10.

151. K. Stone, Natural Resources Canada, *Canadian Minerals Yearbook, 2002: Coal* (Ottawa, Canada, November 2003), web site www.nrcan.gc.ca.

152. IEA Coal Research, *CoalPower 4 Database* (October 2001).

153. Energy Information Administration, *Quarterly Coal Report, October-December 2002*, DOE/EIA-0121 (2002/4Q) (Washington, DC, March 2003), Table 10; SSY Consultancy and Research Ltd, *SSY's Coal Trade Forecast*, Vol. 12, No. 4 (London, United Kingdom, September 2003); and K. Stone, Natural Resources Canada, *Canadian Minerals Yearbook, 2002: Coal* (Ottawa, Canada, November 2003), web site www.nrcan.gc.ca.

154. Energy Information Administration, *Annual Energy Review 2002*, DOE/EIA-0384(2002) (Washington, DC, October 2003), Table 7.4.

155. Energy Information Administration, *Annual Prospects for World Coal Trade 1987*, DOE/EIA-0363(87) (Washington, DC, May 1987), Tables A2 and A3.

156. Energy Information Administration, *Coal Data: A Reference*, DOE/EIA-0064 (93) (Washington, DC, February 1995), pp. 33-35; World Coal Institute, "Coal in the Steel Industry," in *Coal: Power for Progress, Fourth Edition*, web site www.wci-coal.com (March 2000).

157. International Energy Agency, *Databases for the Coal Information 2003*, web site data.iea.org.

Electricity

Electricity consumption nearly doubles in the IEO2004 projections. Developing nations in Asia are expected to lead the increase in world electricity use.

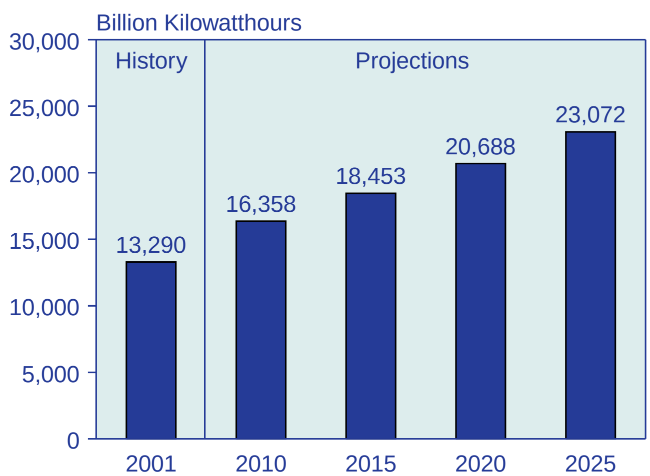
World net electricity consumption is expected nearly double to over the next two decades, according to the *International Energy Outlook 2004* (*IEO2004*) reference case forecast. Total demand for electricity is projected to increase on average by 2.3 percent per year, from 13,290 billion kilowatthours in 2001 to 23,072 billion kilowatthours in 2025 (Figure 60 and Table 14).

Much of the growth in new electricity demand is expected to come from the countries of the developing world. At present, developing countries, with more than 75 percent of the world's population, account for only about one-third of the world's electricity consumption (Figure 61). Access to reliable supplies of electricity among the emerging economies will be necessary to fuel the robust economic growth projected for the region as a whole. Many governments of developing countries have recognized the need to increase their citizens' access to electricity. They have implemented strategies such as privatization to increase investment in the electricity sector, enacting government policies to encourage investment from potential foreign participants, and introducing rural electrification schemes aimed at bringing electricity to rural communities, both to improve standards of living and to increase the productivity of rural societies.

Electricity use in the industrialized nations is expected to increase more slowly than in the developing world, averaging 1.6 percent per year in the *IEO2004* reference case, compared with 3.5 percent per year for the developing world. In the industrialized world, the electricity sector is well established, and equipment efficiency gains are expected to temper the growth in electricity demand. In addition, populations in Japan and Western Europe are expected either to remain at current levels or to decline slightly toward the end of the forecast period, and as a result it is unlikely that demand for electricity in the residential sector will increase substantially.

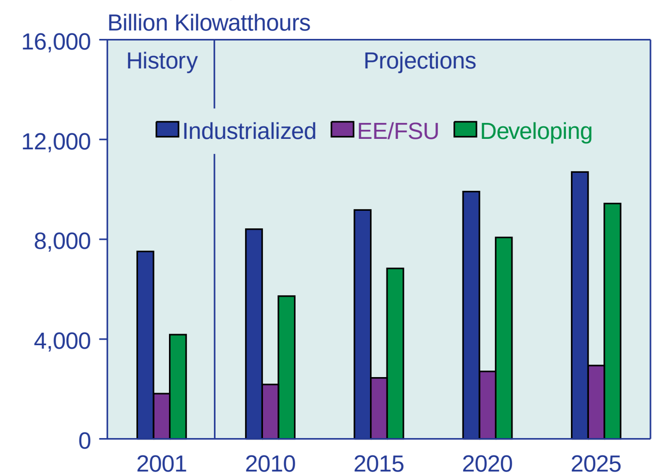
Electricity demand among the transitional economies of Eastern Europe and the former Soviet Union (EE/FSU) is expected to increase at an average annual rate of 2.0 percent over the 2001-2025 period—higher than the 1.5-percent average annual increase over the past 30 years, mostly as a result of the precipitous drop in electricity use that followed the fall of the Soviet regime in the early 1990s. Net electricity consumption in the

Figure 60. World Net Electricity Consumption, 2001-2025



Sources: **2001:** Energy Information Administration (EIA), calculated by the Office of Integrated Analysis and Forecasting, based on estimates of fuel inputs for electricity generation and assumed average generation efficiencies by fuel type. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

Figure 61. World Net Electricity Consumption by Region, 2001-2025



Sources: **2001:** Energy Information Administration (EIA), calculated by the Office of Integrated Analysis and Forecasting, based on estimates of fuel inputs for electricity generation and assumed average generation efficiencies by fuel type. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

EE/FSU fell by 24 percent between 1989 and 1998. Although demand has been on the rise since 1998, it is not expected to return to its 1989 level until after 2010. The region as a whole has shown positive economic growth since 1998 (and Eastern Europe alone since 1993), but upgrades to generating equipment have improved efficiency so that electricity generation has not increased at the same pace as gross domestic product (GDP).

This chapter begins with a discussion of the present fuel mix used for electricity generation and how the mix might change over the forecast period. Next, regional electricity markets are reviewed, considering legislation and policies that could affect their mid-term development, with particular attention to privatization, efforts to increase fuel diversity, and policies in place to improve rural electrification among the developing nations of the world.

Primary Fuel Use for Electricity Generation

The mix of primary fuels used to generate electricity has changed a great deal over the past three decades on a worldwide basis. Coal has remained the dominant fuel, although electricity generation from nuclear power increased rapidly from the 1970s through the mid-1980s,

Table 14. World Net Electricity Consumption by Region, 2001-2025
(Billion Kilowatthours)

Region/Country	2001	Projections				Average Annual Percent Change, 2001-2025
		2010	2015	2020	2025	
Industrialized Countries						
North America	**4,036**	**4,839**	**5,306**	**5,792**	**6,314**	**1.9**
United States[a]	3,386	4,055	4,429	4,811	5,207	1.8
Canada	500	578	630	680	728	1.6
Mexico	150	206	247	301	379	3.9
Western Europe	**2,246**	**2,486**	**2,659**	**2,839**	**3,029**	**1.3**
Industrialized Asia	**1,014**	**1,132**	**1,208**	**1,279**	**1,354**	**1.2**
Japan	788	870	920	965	1,012	1.0
Australia/New Zealand	226	262	288	314	342	1.8
Total Industrialized	**7,296**	**8,456**	**9,173**	**9,910**	**10,697**	**1.6**
EE/FSU						
Former Soviet Union	1,397	1,666	1,862	2,044	2,202	1.9
Eastern Europe	418	515	585	662	739	2.4
Total EE/FSU	**1,815**	**2,181**	**2,447**	**2,706**	**2,941**	**2.0**
Developing Countries						
Developing Asia	**2,650**	**3,723**	**4,508**	**5,342**	**6,274**	**3.7**
China	1,237	1,856	2,322	2,825	3,410	4.3
India	554	751	896	1,053	1,216	3.3
South Korea	231	318	371	419	468	3.0
Other Developing Asia	628	797	919	1,045	1,181	2.7
Middle East	**476**	**635**	**723**	**818**	**926**	**2.8**
Africa	**384**	**499**	**602**	**716**	**808**	**3.1**
Central and South America	**668**	**864**	**1,000**	**1,196**	**1,425**	**3.2**
Total Developing	**4,179**	**5,721**	**6,833**	**8,072**	**9,434**	**3.5**
Total World	**13,290**	**16,358**	**18,453**	**20,688**	**23,072**	**2.3**

[a]Includes the 50 States and the District of Columbia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding.

Sources: **2001:** Energy Information Administration (EIA), calculated by the Office of Integrated Analysis and Forecasting, based on estimates of fuel inputs for electricity generation and assumed average generation efficiencies by fuel type. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

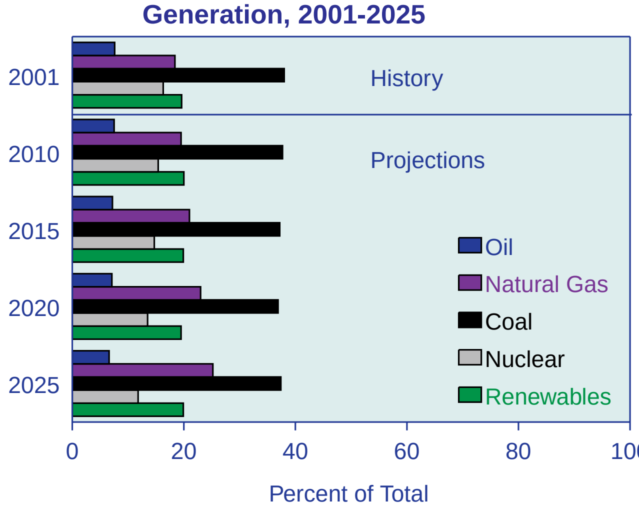
and natural-gas-fired generation has grown rapidly in the 1980s and 1990s. In contrast, in conjunction with the high world oil prices brought on by the oil price shocks after the OPEC oil embargo of 1973-1974 and the Iranian Revolution of 1979, the use of oil for electricity generation has been slowing since the mid-1970s.

In the *IEO2004* reference case, continued increases in the use of natural gas for electricity generation are expected worldwide. Coal is projected to continue to retain the largest market share of electricity generation, but its importance is expected to be moderated somewhat by a rise in natural gas use. The role of nuclear power in the world's electricity markets is projected to lessen as reactors in industrialized nations reach the end of their lifespans. New reactors are expected to be built mainly in the developing world. Generation from hydropower and other renewable energy sources is projected to grow by 57 percent over the next 24 years, but their share of total electricity generation is projected to remain near the current level of 20 percent (Figure 62).

Coal

Coal is an important source of electricity generation in a number of the world's regional markets. Not surprisingly, the countries with the largest coal reserves have electricity markets dominated by coal. For instance, the United States—with the largest share of the world's recoverable coal reserves—generates about one-half of its total electricity from coal. China, India, Germany, Poland, South Africa, and Australia all have substantial coal reserves, and in each case coal-fired generation accounts for more than one-half of electric power production. In both China and India, coal's market share in the electricity sector exceeds 75 percent.

Figure 62. Fuel Shares of World Electricity Generation, 2001-2025



Sources: **2001:** Energy Information Administration (EIA), calculated by the Office of Integrated Analysis and Forecasting, based on estimates of fuel inputs for electricity generation and assumed average generation efficiencies by fuel type. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

Russia has the world's second largest coal reserves and uses coal to produce one-third of its electricity at present. Russia has been able to diversify its electricity markets somewhat more than other coal-rich nations, because it also has ample natural gas and hydroelectric resources and a mature nuclear power program; but because the FSU also has significant coal resources, coal is expected to retain its importance in the region's electric power supply. Coal's share of the electric power market in the FSU is projected to increase slightly, from 23 percent in 2001 to 24 percent in 2025, as nuclear generation decreases.

Competition from natural gas may erode coal's market share in some key countries, but coal's dominance is not likely to decline precipitously. Many of the countries of Western Europe are expected to reduce their use of coal for power generation, with increases in natural-gas-fired generation, renewables, and, in the case of France, nuclear power. Most notably, in Germany, coal's share of energy use for electricity generation was 49 percent in 2001 but is projected to drop rapidly as natural-gas-fired generation and, to a lesser extent, renewable energy use continue to be added for new electric power capacity. As Eastern European electricity markets begin to integrate with Western European markets with the expansion of the European Union (EU), coal use for electricity is also expected to decline. Coal's share of electricity generation in Eastern Europe is projected to fall from 58 percent in 2001 to 44 percent in 2010 and to 24 percent in 2025.

In markets where coal has not been a particularly important contributor to electricity generation, there are unlikely to be significant increases in coal use. Canada, Mexico, Central and South America, and the Middle East all use coal for less than 20 percent of their total electricity generation. Canada and Central and South America rely heavily on hydroelectric power for their electricity supplies, and Mexico and the Middle East rely on oil and natural gas. In each of those markets, coal is projected to account for less than 20 percent of electricity generation in 2025.

Natural Gas

Electricity markets of the future are expected to depend increasingly on natural-gas-fired generation. Industrialized nations are increasing their use of combined-cycle gas turbines, which usually are cheaper to construct and more efficient to operate than other fossil-fuel-fired generation. Natural gas is also seen as a much cleaner fuel than other fossil fuels. Worldwide, natural gas use for electricity generation is projected to be more than twice as great in 2025 as it was in 2001, as technologies for natural-gas-fired generation continue to improve and ample gas reserves are exploited. In the developing world, natural gas is expected to be used to diversify electricity fuel sources, most notably in Central and South America, where heavy reliance on hydroelectric power has led to shortages and blackouts during periods of severe drought.

Natural gas has proven to be a popular choice for electricity generation in many countries. Worldwide, consumption of natural-gas-fired electricity increased by an average of 6.9 percent per year from 1970 to 2001—second only to nuclear power's average annual growth rate of 17.5 percent over the same period. In some cases, governments have tried to slow the growth of natural gas use for power generation. In the 1970s, the U.S. Government passed legislation that effectively barred utilities from expanding their use of natural gas (as well as petroleum) [*1*]. The Energy Supply and Environmental Coordination Act of 1974 allowed the Federal Government to prohibit electric utilities from burning gas or oil. Nonutility generators were largely responsible for the increase in gas-fired power generation in the United States during the 1990s, until electricity deregulation, the belief that sufficient natural gas reserves existed, and the perceived environmental advantages of natural gas over coal resulted in a relaxation of the restrictions on natural gas.

In the United Kingdom, natural gas use for electric power grew rapidly in the 1990s and was characterized by some analysts as the "dash for gas." The fast-paced growth alarmed the U.K. government, both because of the fear that there would not be sufficient supplies of natural gas to meet the growing demand of electric power companies and because the government wished to allow the country's coal industry to be competitive with natural gas [*2*]. As a result, the government issued a moratorium on construction of new natural gas capacity in 1998, which was in place until November 2000 [*3*]. Immediately after the restrictions were revoked, plans were announced to construct five new electricity generators fueled by natural gas.

Natural gas has been an important fuel for electricity generation among the countries of the FSU for the past three decades, accounting for between 40 and 50 percent of their total natural gas use. Dependence on natural gas for electricity generation is expected to remain strong in the FSU: in 2025, gas-fired generation is projected to account for 51 percent of the FSU's total electricity supply.

Oil

The role of oil in the world's electricity generation market is generally expected to diminish over the next two decades in much of the world. Energy security concerns, as well as environmental considerations, have already led many nations to reduce their use of oil for electricity generation. In the Middle East, however, oil holds a significant share of the generation fuel market. With much of the world's oil resources, the Middle East is expected to continue to generate a large share of its electricity with oil. In other parts of the developing world, where many countries still rely on traditional fuels (such as wood and animal dung) as energy sources, oil use for electricity may increase somewhat as nations switch to diesel-fired generators until their populations are able to be connected to national grids.

Nuclear Power

In the *IEO2004* reference case, the nuclear share of the world's total electricity supply is projected to fall from 16 percent in 2001 to 12 percent in 2025. The reference case assumes that the currently prevailing trend away from nuclear power in the industrialized countries will not be reversed, and that retirements of existing plants as they reach the end of their designed operating lifetimes will not be balanced by the construction of new nuclear power capacity in those countries. In contrast, rapid growth in nuclear power capacity is projected for some countries in the developing world.

For the most part, and under most economic assumptions, nuclear power is a relatively expensive option for electricity generation when compared with natural gas or coal, particularly for nations with access to inexpensive sources of fossil fuels, and without world compliance with carbon emission reduction policies, such as the Kyoto Protocol. In addition, there is strong public sentiment against nuclear power in many parts of the world, based on concerns about plant safety, radioactive waste disposal, and the proliferation of nuclear weapons. The economics of nuclear power may be more favorable in countries where other energy fuels (mostly imported) are relatively expensive.

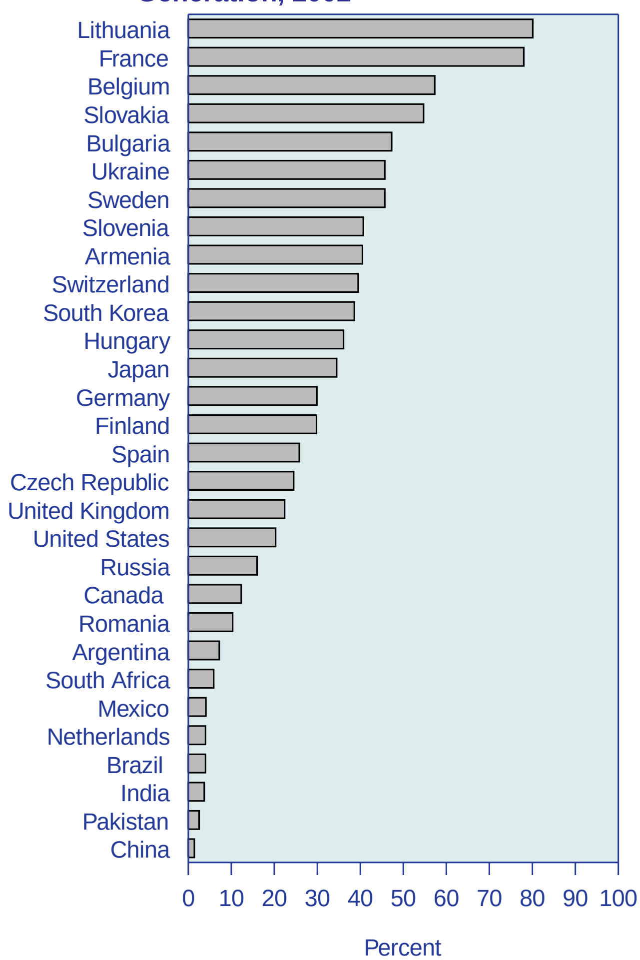
Nineteen countries depended on nuclear power for at least 20 percent of their electricity generation in 2002 (Figure 63). In absolute terms, the world's total nuclear power capacity is projected to increase from 353 gigawatts in 2001 to 385 gigawatts in 2025 in the reference case (Table 15). The largest additions of nuclear capacity are expected in Asia (China, India, Japan, and South Korea) and in Russia. China is projected to add nearly 19 gigawatts of nuclear capacity in the *IEO2004* reference case, South Korea 15 gigawatts, Japan 11 gigawatts, India 6 gigawatts, and Russia 6 gigawatts. (Japan and Russia are also expected to retire 5 gigawatts and 7 gigawatts of existing nuclear capacity, respectively, between 2001 and 2025.)

In other parts of the world, life extensions, higher capacity factors, and capacity uprates are expected to offset some of the capacity lost through plant retirements. For example, life extensions and higher capacity factors are expected to play a major role in sustaining the U.S. nuclear industry. Thus, despite a declining share of global electricity production, nuclear power is projected to continue in its role as an important source of electric power.

At the end of 2003 there were 441 nuclear power reactors in operation around the world [*4*], and another 34 were under construction. Two new nuclear power plants began operation in China in 2003, and four were permanently shut down in the United Kingdom. Construction on North Korea's nuclear reactor program was suspended in November 2003, pending the outcome of the ongoing six-party negotiations (North Korea, China, Japan, Russia, South Korea, and the United States) over North Korea's nuclear weapons program [*5*].

Recently, significant improvements in operating and safety performance have improved the image of nuclear power and its future global prospects. For instance, the world's average nuclear power plant availability factor

Figure 63. Nuclear Shares of National Electricity Generation, 2002



Source: International Atomic Energy Agency, Reference Data Series 2, "Power Reactor Information System," web site www.iaea.org/programmes/a2/.

improved from 73 percent in 1990 to 84 percent in 2002, and average U.S. capacity factors improved from 71 percent in 1992 to 91 percent in 2002 [*6*]. Greater capacity utilization allowed the U.S. nuclear power industry to increase net generation by 19 percent between 1991 and 2001, despite a nearly 2-percent decrease in operable nuclear capacity over the same period. At the same time, both overseas and in the United States, nuclear plant safety measures have improved considerably. Nuclear power has also been advocated as a desirable option for reducing greenhouse gas emissions.

Nowhere is the decision to build nuclear power capacity left entirely to corporations or utilities that would base their decisions solely on economic grounds. In general, government policy (with an eye to public opinion) guides the development of nuclear power. National policies have evolved considerably since the first nuclear power reactors were connected to the grid in the United Kingdom, United States, and Soviet Union during the 1950s. Shortly after the first oil crisis exposed the vulnerability of world economies to petroleum price shocks, nations attempted to increase their access to more secure sources of fuel, and subsequent oil price shocks tended to reinforce their desires. As a result, many nations pursued nuclear power programs aggressively during the 1970s, in most cases with strong public support.

Subsequently, however, accidents at Three Mile Island in the United States in 1979 and at Chernobyl in the Soviet Union in 1986 pushed public opinion and national energy policies away from nuclear power as a source of electricity. In the United States, massive cost overruns and repeated construction delays—both caused in large part by regulatory reactions to the accident at Three Mile Island—essentially ended U.S. construction of nuclear power plants. Similarly, both before and after the Chernobyl accident, several European governments had announced their intentions to withdraw from the nuclear power arena. Sweden committed to a phaseout of nuclear power in 1980 after a national referendum. Both Italy and Austria have abandoned nuclear power entirely, and Austria has also been a strong opponent of nuclear power programs in Eastern Europe that it considers to be unsafe. Belgium, Germany, and the Netherlands have committed to gradual phaseouts of their nuclear power programs, although in some cases such commitments have proven difficult to carry through. Given the periodic changes in political leadership that can shift official government positions on nuclear power, it is difficult to assess the degree to which current commitments for or against nuclear power will be maintained.

Many issues still may impede the expansion of the nuclear power industry. Nuclear waste disposal remains a key concern. High-level nuclear waste must be stored for thousands of years, and there is general consensus that stable, deep, geological formations are the best locations for waste repositories. The greatest concern over the storage of high-level nuclear waste is that over such a long period of time, the containers in which the waste is stored could eventually leak. Although most nations have identified potential underground storage sites and have conducted geological and geophysical tests as to their suitability, no underground storage site has progressed beyond the planning stage. In the United States, which is perhaps the farthest advanced in the planning stage, President Bush in February 2002 authorized the construction of a nuclear waste repository at Yucca Mountain in Nevada [*7*].

Another potential drawback to nuclear power is the fear that reactors might be used for purposes of developing nuclear weapons. The events that have unfolded in North Korea over the past several years underscore the concern that can arise over the possibility of nuclear proliferation. For many years, North Korea insisted that it would not use its Yongbyong nuclear power reactor to create weapons-grade plutonium; then, in 2003, the government announced that it possessed nuclear weapons [*8*]. Nuclear programs in other countries, such as Iran and Libya, have also recently come under scrutiny by the world community. After Libya agreed to dismantle its nuclear program—which involved the purchase of nuclear power designs from Pakistani scientist Abdul Qadeer Khan—the International Atomic Energy Agency announced that finding out whether other countries had acquired nuclear weapons technology was "an important and urgent concern for us" [*9*]. Khan also admitted selling nuclear secrets to Iran and North Korea.

In the wake of the events in Libya, North Korea, and Iran, the Bush Administration proposed several new initiatives for curbing the spread of nuclear weapons materials and expertise [*10*]. Under the proposal, the Nuclear Suppliers Group—comprising 40 member countries

Table 15. World Installed Nuclear Capacity by Region, 2001-2025
(Gigawatts)

Region/Country	2001	Projections 2010	2015	2020	2025
Industrialized Countries	**279**	**292**	**291**	**280**	**263**
North America	**110**	**116**	**118**	**119**	**116**
United States[a]	98	101	102	103	103
Canada	10	14	14	15	12
Mexico	1	1	1	1	1
Western Europe	**126**	**125**	**120**	**104**	**93**
United Kingdom	12	10	7	6	4
France	63	67	68	70	70
Germany	21	17	13	1	0
Japan	**43**	**50**	**53**	**57**	**54**
EE/FSU	**46**	**53**	**57**	**52**	**49**
Former Soviet Union	35	41	43	39	36
Russia	21	26	28	25	21
Eastern Europe	12	12	14	13	13
Developing Countries	**28**	**47**	**60**	**68**	**73**
Developing Asia	**23**	**41**	**53**	**62**	**67**
China	2	9	16	18	21
India	3	6	7	9	9
Middle East	**0**	**1**	**2**	**2**	**2**
Africa	**2**	**2**	**2**	**2**	**2**
Central and South America	**3**	**3**	**3**	**3**	**3**
Total World	**353**	**392**	**407**	**401**	**385**

[a]Includes the 50 States and the District of Columbia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding.

Source: **United States:** Energy Information Administration (EIA), *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), web site www.eia.doe.gov/aeo/. **Foreign:** EIA, based on detailed assessments of country-specific nuclear power programs.

with nuclear technologies—would refuse to sell enrichment and reprocessing equipment to any state that does not already possess full-scale, functioning equipment and reprocessing plants. The proposal also would expand the effort to intercept suspected weapons of mass destruction on ships, through cooperation with Interpol and other law enforcement mechanisms, and would require that all nations sign the International Atomic Energy Agency's "Additional Protocol," expanding the agency's authority to investigate clandestine nuclear activities.

Hydroelectricity and Other Renewables

In the *IEO2004* reference case, moderate growth in the world's consumption of hydroelectricity and other renewable energy resources is projected over the next 24 years. Most renewable energy sources are not expected to compete economically with fossil fuels in the mid-term forecast. In the absence of significant government policies, such as those aimed at reducing the impacts of carbon-emitting energy sources on the environment, it will be difficult to extend the use of renewables on a large scale. *IEO2004* projects that consumption of renewable energy for electricity production worldwide will grow by 57 percent, from 32 quadrillion Btu in 2001 to 49 quadrillion Btu in 2025 (Table 16).

Much of the projected growth in renewable generation is expected to result from the completion of large hydroelectric facilities in developing countries, particularly in

Table 16. World Energy Consumption for Electricity Generation by Region and Fuel, 2001-2025
(Quadrillion Btu)

Region/Country	2001	Projections 2010	2015	2020	2025	Average Annual Percent Change, 2001-2025
Industrialized Countries						
Oil	5.1	4.5	4.8	5.0	5.3	0.1
Natural Gas	14.4	18.5	21.8	25.7	29.6	3.1
Coal	32.1	34.4	35.7	37.8	41.7	1.1
Nuclear	21.0	22.9	23.2	23.3	21.9	0.2
Renewables	16.4	19.5	20.8	21.9	23.1	1.4
Total	**89.0**	**99.8**	**106.4**	**113.6**	**121.5**	**1.3**
Eastern Europe/Former Soviet Union						
Oil	0.9	0.8	0.9	1.0	1.1	0.6
Natural Gas	8.1	10.2	11.9	14.1	16.5	3.0
Coal	6.8	7.9	8.1	8.1	7.9	0.6
Nuclear	3.0	3.4	3.5	3.2	2.9	-0.2
Renewables	3.1	3.8	4.2	4.2	4.4	1.6
Total	**21.9**	**26.2**	**28.5**	**30.6**	**32.8**	**1.7**
Developing Countries						
Oil	6.1	9.2	9.8	10.8	10.7	2.4
Natural Gas	7.1	8.9	11.3	14.3	19.0	4.2
Coal	22.2	30.6	35.7	41.0	47.1	3.2
Nuclear	2.2	3.5	4.7	5.4	5.7	4.0
Renewables	12.0	15.4	17.5	19.7	21.9	2.5
Total	**49.6**	**67.6**	**79.0**	**91.3**	**104.2**	**3.1**
Total World						
Oil	12.2	14.5	15.5	16.7	17.0	1.4
Natural Gas	29.6	37.7	44.9	54.1	65.2	3.3
Coal	61.1	73.0	79.5	86.9	96.7	1.9
Nuclear	26.2	29.8	31.4	31.8	30.4	0.6
Renewables	31.5	38.6	42.5	45.9	49.4	1.9
Total	**160.5**	**193.6**	**213.9**	**235.5**	**258.6**	**2.0**

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

Sources: **2001:** Energy Information Administration (EIA), calculated by the Office of Integrated Analysis and Forecasting, based on estimates of fuel inputs for electricity generation and assumed average generation efficiencies by fuel type. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

developing Asia, where the need to expand electricity production often outweighs concerns about environmental impacts and the relocation of populations to make way for large dams and reservoirs. China, India, and other countries in developing Asia are constructing or planning new, large-scale hydroelectric facilities. The first electricity generating units of China's 18,200-megawatt Three Gorges Dam hydropower project began generating power in mid-2003, and India's 1,500-megawatt Nathpa Jhakri hydropower project was commissioned in October 2003.

Many nations of Central and South America also have plans to expand their already well-established hydroelectric resources. Brazil, Peru, and even oil-rich Venezuela have plans to increase hydroelectric capacity over the next decade. Brazil alone anticipates tenders for 17 hydroelectric projects in 2004, with a combined installed capacity of 4,149 megawatts, despite a crippling drought in 2000-2001 that resulted in electricity rationing and threatened brownouts. Many of Brazil's new hydroelectric projects will be located in the northeastern part of the country, which was not as severely affected by the drought. In general, however, the nations of Central and South America are not expected to expand hydroelectric resources dramatically but instead are expected to invest in other sources of electricity—particularly natural-gas-fired capacity—that will allow them to diversify electricity supplies and reduce their reliance on hydropower.

Hydroelectric capacity outside the developing world is not expected to grow substantially. Among the industrialized nations, only Canada has plans to construct any sizable hydroelectric projects over the forecast period. Hydro Québec alone is planning to add some 6,000 megawatts of additional hydroelectric capacity within the next decade. In the EE/FSU countries, most additions to hydroelectric capacity are expected to come from repair or expansion of existing plants. In the industrialized and EE/FSU regions, most hydroelectric resources either have already been developed or lie far from population centers.

Wind power has shown the fastest growth of all renewable energy sources in recent years. In many countries of the developing world, small wind and wind-hybrid installations are an effective method for bringing electric power to rural areas that cannot be connected to national grids (see box on page 109). In the industrialized world, particularly strong growth in wind power has been seen in recent years in Western Europe. Germany, Spain, and Denmark were all among the top five wind installers in 2002; Germany added the most wind capacity in 2002, installing 3,247 megawatts to bring the country's total installed wind capacity to 12,000 megawatts [*11*]. The United States installed 687 megawatts of new wind capacity in 2002, after a record year of 1,695 megawatts of new wind capacity in 2001. U.S. wind capacity additions in 2003 were expected to be even stronger, totaling an estimated 1,664 megawatts, in view of the December 31, 2003, expiration of a production tax credit for wind power; although a provision in proposed U.S. energy legislation includes a bipartisan plan for extending the tax credit through 2006, the U.S. Senate has not yet passed the bill.

The *IEO2004* projections for hydroelectricity and other renewable energy resources include only on-grid renewables. Non-marketed (noncommercial) fuels from plant and animal sources are an important source of energy, particularly in the developing world, and the International Energy Agency has estimated that some 2.4 billion people in developing countries depend on traditional biomass for heating and cooking [*12*]. Comprehensive data on the use of non-marketed fuels are not available, however, for inclusion in the projections. Moreover, dispersed renewables (renewable energy consumed on the site of its production, such as solar panels used to heat water) are not included in the projections, also because there are few comprehensive sources of international data on their use.

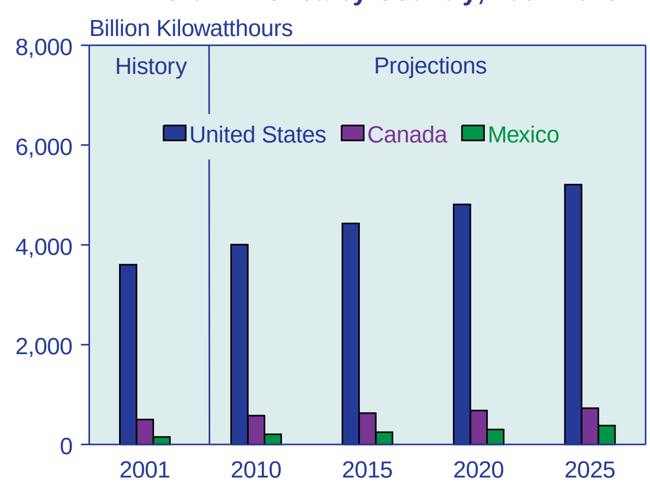
Regional Developments

North America

United States

In the United States, electricity demand is projected to increase by 1.8 percent per year on average, from 3,386 billion kilowatthours in 2001 to 5,207 billion

Figure 64. Net Electricity Consumption in North America by Country, 2001-2025



Sources: **2001:** Energy Information Administration (EIA), calculated by the Office of Integrated Analysis and Forecasting, based on estimates of fuel inputs for electricity generation and assumed average generation efficiencies by fuel type. **Projections:** United States: Energy Information Administration (EIA), *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), web site www.eia.doe.gov/aeo/. Canada and Mexico: EIA, System for the Analysis of Global Energy Markets (2004).

Small Wind Power

Small wind turbines (installed capacity up to 100 kilowatts) have the potential to penetrate markets in rural areas of developing countries. There are more than 5,000 units installed worldwide. The United States, a leading producer, has four manufacturers of small turbines, which manufacture about 30 percent of the units sold worldwide.[a] In addition to wind-only applications, there are numerous hybrid applications, involving wind and other renewables, wind with water pumping systems, or wind with water treatment systems. Hybrids provide a more stable power supply, by smoothing out some of the seasonal variation inherent in wind-only systems.

One barrier to the market penetration of small wind turbines is cost. As with many technologies, there are economies of scale associated with small wind turbine systems. At the 50-watt level, they cost about $8,000 per kilowatt; at the 300-watt level, the cost drops to between $1,500 and $2,500 per kilowatt; and at the 1.5-kilowatt level, the cost is $1,500 per kilowatt.

In the past, reliability has been a major concern for developers of wind turbines; however, some new turbine systems can operate for 5 years without major maintenance or overhaul. This does not negate the need for regular maintenance and visual inspection, but it shows the progress over earlier versions, which had frequent outages.[b]

Another concern is intermittence—the inability to operate continuously because of a lack of adequate wind resources at some times. In most locations, because of the seasonal nature of wind, there are periods when the wind is either too weak or too strong for the turbine to operate effectively, and capacity factors of 20 to 30 percent are common.

Wind turbine systems can be built in large clusters (farms) to smooth out some of the fluctuations observed with a single turbine. Alternatively, the turbines can be installed with battery energy storage, diesel backup, or photovoltaic hybrids (although wind-photovoltaic hybrids can be considerably more expensive than turbines installed in a cluster). In order to capture the best wind resource, a wind turbine should be at least 30 feet above any obstacles within 300 feet. A 250-watt turbine can be installed on a 30- to 50-foot tower, and a 10-kilowatt turbine may need an 80- to 120-foot tower.

Another consideration is that windy sites may be far from population or load centers. In such situations, a determination must made as to whether it is cheaper to construct a turbine at an optimal wind location and build transmission lines to bring the power to load centers, or to build it at a less then optimal site with lower transmission costs. Wind also follows seasonal patterns, with the best performance in winter months and the poorest in summer months.[b]

An interesting example of a water treatment system using a hybrid wind turbine and photovoltaic battery has recently been installed in Afghanistan. The idea for the project came from experience with photovoltaic and micro-hydro-powered ozone-based water treatment systems successfully deployed around the Annapurna Circuit in Nepal and with wind and solar installations in Baluchistan province in Pakistan. In the Parwan, Wardak, and Kapisa Districts of Afghanistan, 11 standalone wind-based water treatment systems have been installed and are operating successfully. One water treatment system was installed in a high school in Kabul to provide clean water to the school and community residents. Electricity from the systems is not sold but rather is used directly for water purification or in the local schools.

The equipment for the Afghan water treatment systems consists of a Bergey 1-kilowatt wind turbine on a 42-foot tower, 180 watts of photovoltaic panels, a battery bank, and an inverter. The water treatment technology uses about 160 watts of power to generate 2 grams of ozone per hour. The water is treated in batches, and most communities can treat about 2,000 to 4,000 liters of drinking water per day. These small hybrid systems are easy to ship and install and do not require special tools or concrete. The wind turbine and tower are assembled on the ground and tilted up with a hand winch. At a cost of $5,900 to $6,400 (2003 dollars),[c] a 1.2-kilowatt hybrid system can produce 3 to 5 kilowatthours of electricity per day.[d] Similar systems have been installed in Australia, Bangladesh, Bolivia, Brazil, China, Chile, Fiji, Indonesia, Mali, Mexico, Morocco, and Russia.

[a]American Wind Energy Association, web site www.awea.org. The manufacturers are Bergey Windpower (www.bergey.com), South-West Windpower (www.windenergy.com), WindTech International, L.L.C. (www.windmillpower.com), and Wind Turbine Industries Corp. (www.windturbine.net).

[b]M. Bergey, "A Primer on Small Turbines," web site www.bergey.com/school/primer.html, previously published in *Home Power* and *Backwoods Home* magazines (2002).

[c]Cost does not include wiring, shipping, or installation.

[d]The systems generate 3 to 5 kilowatthours net AC energy after storage and conversion losses and can produce close to 5 kilowatthours in good wind resource areas. Capacity factors for the systems are typically 20 percent before storage and conversion losses.

kilowatthours in 2025 (Figure 64). Demand for electricity has slowed in the United States over the past several decades, owing to increased market saturation of electric appliances, improvements in equipment efficiency and utility investments in demand-side management programs, and more stringent equipment efficiency standards. In the forecast, growth in demand for office equipment and personal computers is offset by slowing or reduced demand for space heating and cooling, refrigeration, water heating, and lighting.

The natural gas share of electricity generation (including generation in the end-use sectors) is projected to increase from 18 percent in 2001 to 20 percent in 2025, lower than the 29 percent forecast for 2025 in last year's report. The coal share of generation is projected to increase from 49 percent in 2001 to 52 percent in 2025 as rising natural gas prices improve the cost competitiveness of coal-fired technologies. Some 112 gigawatts of new coal-fired generating capacity is expected to be constructed by 2025.

Nuclear generating capacity in the *IEO2004* forecast is projected to increase from 98.2 gigawatts in 2001 to 102.6 gigawatts in 2025, including uprates of existing plants equivalent to 3.9 gigawatts of new capacity by 2025. This is a change from last year's forecast, where total nuclear capacity reached a projected peak of 100.4 gigawatts in 2006 before declining to 99.6 gigawatts in 2025. In contrast to the *IEO2003* forecast, no existing U.S. nuclear units are retired in the *IEO2004* reference case. The forecast assumes that the Browns Ferry nuclear plant will begin operation in 2007 but projects that no new nuclear facilities will be built before 2025, based on the relative economics of competing technologies.

Renewable technologies are projected to grow slowly because of the relatively low costs of fossil-fired generation and because competitive electricity markets favor less capital-intensive technologies in the competition for new capacity. Where enacted, State renewable portfolio standards, which specify a minimum share of generation or sales from renewable sources, are included in the forecast. Eleven States (California, Nevada, Arizona, New Mexico, Texas, Iowa, Wisconsin, Maine, Massachusetts, Connecticut, and Pennsylvania) currently have renewable portfolio standards in place. In addition, Minnesota and Illinois have set renewable goals but not renewable portfolio standards [***13***].

Total renewable generation, including combined heat and power generation, is projected to increase from 291 billion kilowatthours in 2001 to 519 billion kilowatthours in 2025, at an average annual growth rate of 2.4 percent. U.S. renewable energy use grows more quickly in the *IEO2004* reference case than in last year's report, where renewable generation was projected to grow by only 2.1 percent per year from 2001 to 2025.

Canada

Electric power in Canada is constitutionally the responsibility of the provinces, except for electricity traded across provincial or international borders. The electricity sectors are, for most of the country's 10 provinces, largely province-owned, although there are some privately-owned utilities and some independent power producers operating in the country. Canada's three largest electric utilities are Ontario Power Generation, Hydro-Québec, and British Columbia Hydro.

The provinces of Alberta and Ontario have introduced legislation to deregulate and privatize their power sectors. Alberta was the first province to introduce privatization legislation in 1995, and in January 2001 retail customers were allowed to choose their own electricity suppliers [***14***]. Ontario introduced privatization legislation in 1998 and deregulation began there in 2002. The process slowed substantially, however, in the aftermath of California's energy crisis. In Ontario, sharp price increases after deregulation was implemented led the government to intervene and impose a retail electricity price cap of 4.3 cents per kilowatthour (Canadian) for residential and other small consumers in November 2002. The new Liberal government, upon taking office in late 2003, became concerned about the financial implications of the cap for Ontario Power Generation and for the government deficit. As an interim measure, the cap will be raised in April 2004 to 4.7 cents per kilowatthour for the first 750 megawatthours and 5.5 cents per kilowatthour for consumption above that. This pricing regime is to remain in place until May 2005, by which time the Ontario Energy Board is to develop a new pricing system [***15***].

Net electricity consumption in Canada is expected to increase by 1.6 percent per year between 2001 and 2025, from 500 billion kilowatthours to 728 billion kilowatthours. Hydroelectric power provides about 60 percent of Canada's generation, and although its share slips slightly over the forecast period, hydropower is projected to continue dominating the electric power fuel mix in Canada through 2025. In the *IEO2004* reference case, hydropower's share of total energy use for electricity generation falls to 58 percent in 2025.

There are plans to expand hydroelectric capacity in Canada. In particular, Hydro Québec has more than 6,000 megawatts of hydroelectric capacity either under construction or planned in Québec Province, including the 3,880-megawatt Saint Marguerite facility (to be completed by the end of 2004); 1,480-megawatt Eastmain (2008); 220-megawatt Grande Mere (2005); 526-megawatt Tolnustoouc (2005); and 385-megawatt Peribonka (2008) [***16***].

There are currently 17 nuclear power reactors operating in Canada. Although no new nuclear reactors are under construction, there are plans to bring four units of Ontario Province's Pickering reactors back into operation over the next several years, adding 2,060 megawatts of nuclear capacity by 2007. This follows the reconnection of the 790-megawatt Bruce 4 reactor to the Ontario electricity grid in December 2003 and the reconnection of the 750-megawatt Bruce 3 unit in January 2004 [***17***]. Both Bruce units had been shut down since 1998. The return of the two units will mean, when the temporarily suspended Bruce 8 unit is brought back on line, that Bruce Power will be able to meet the needs of 20 percent of Ontario's electric power demand with the six nuclear units [***18***]. Canada's nuclear capacity is projected to increase from 10,018 megawatts in 2001 to 15,207 megawatts in 2020 before beginning to decline to 12,351 megawatts at the end of the *IEO2004* forecast in 2025.

The return of the Bruce and Pickering nuclear units in Ontario should help the provincial government in its efforts to eliminate coal-fired generation in the province by 2007 [***19***]. In 2003, Ontario had around 8,000 megawatts of coal-fired capacity [***20***]. The Electricity Conservation and Supply Task Force was organized to determine how Ontario's electricity sector should evolve to both phase out coal-fired generation and at the same time ensure a secure supply of electricity. The task force suggested that a combination of nuclear power improvements and uprates, along with additional nonhydropower renewable energy sources, could allow Ontario to meet its target for coal's removal; however, it also warned that removing the province's five baseload coal generators could put reliability at risk in the short term. In addition, the task force recommended that electricity demand growth rates be reduced to 0.5 percent per year, from the 1.7 percent per year growth experienced over the past decade, and that the province consider importing hydroelectric power from Manitoba, Québec, and Labrador for "intermediate and peaking purposes." It also cautioned that constructing the necessary transmission lines "would be costly, and would take time" [***21***].

Ontario's recently elected Liberal government has approved a renewable portfolio standard (RPS) that sets aggressive targets and time frames for increasing the amount of renewable capacity in the province [***22***]. The RPS calls for 300 megawatts of new wind capacity by 2005 and 2,000 megawatts by 2010. In addition, it calls for the development of about 700 megawatts of small hydropower and biomass projects.

Other provinces are also seeing interest in developing renewable energy resources, particularly wind. In 2003, a 75-megawatt wind project was completed in Alberta, near Fort Macleod. Construction on the $76 million McBride Lake Wind Farm began in November 2002, and the first electricity from the project was generated in February 2003 [***23***]. The last of the 114 wind turbines was installed in June 2003. The project was supported by Canada's $196 million Wind Power Production Incentive program, whose goal is to increase the amount of wind power in Canada by an estimated 500 percent [***24***]. The government of Canada is expected to contribute approximately $25 million to the McBride facility over a 10-year period.

The Canadian company Suncor Energy began construction of a 30-megawatt wind project in southern Alberta in September 2003 [***25***]. The $35 million project, a joint venture between Suncor and EHN Wind Power Canada, will be located about 4 miles west of Magrath. It is scheduled for completion by the end of 2004. Suncor Energy also completed an 11-megawatt, $17 million wind project in Saskatchewan in 2002. In addition, Hydro Québec is planning to purchase 1,000 megawatts of wind power over the next 10 years, mostly from independent power producers in the Gaspésie region [***26***].

Mexico

In Mexico, the electric power sector remains largely under state control. Electric power generation is currently the only segment of the electricity sector that allows some private-sector participation, the result of a 1992 amendment to Mexico's Electricity Law [***27***]. Private companies are allowed to generate electricity for areas not considered "public service." They include generating electricity for export and generating electricity for public service during an emergency. Self- or cogenerators and small producers may generate electricity for their own use, and independent power producers are permitted to sell excess power to the Federal Electricity Commission (CFE) under long-term contracts.

CFE and Luz y Fuerza Centro (LFC) are Mexico's two state-owned electricity companies. CFE generates about 90 percent of the country's electricity and LFC about 2 percent, with 4 percent coming from the Mexican state-owned oil company Pemex and the remainder from private-sector generators. The Mexican Energy Secretariat has estimated that an additional 13,000 megawatts of new capacity will be needed between 1999 and 2005 to meet demand. The Fox Administration proposed reforming Mexico's electricity sector as a way of meeting growing electricity demand, but the Mexican Congress has not adopted the reforms to date.

Net electricity consumption in Mexico is projected to more than double in the *IEO2004* forecast, from 150 billion kilowatthours in 2001 to 379 billion kilowatthours in 2025. Much of the country's generation is currently produced from fossil fuels. Oil accounts for about 50 percent of generation, natural gas about 23 percent, and coal a very modest amount. Fossil fuels are expected to dominate the sector in the mid-term, with a continuing switch from oil to natural gas both for environmental reasons and to diversify the sector.

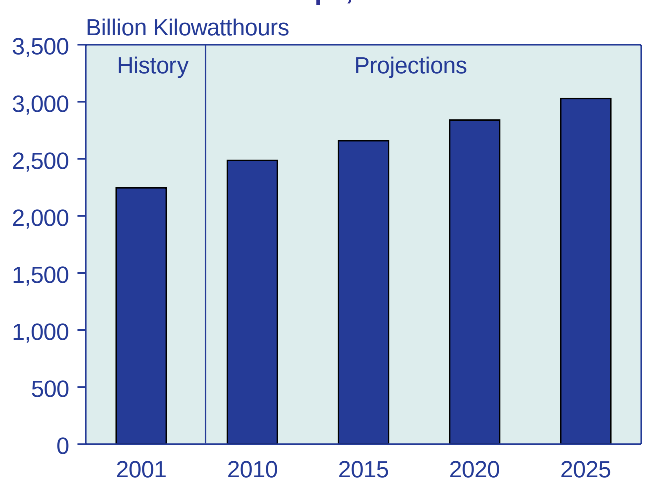
Mexico has two nuclear power plants at Laguna Verde, Veracruz, each with a 680-megawatt installed capacity. There are no plans for Mexico to add nuclear power over the projection period. The country also has around 10,000 megawatts of installed hydroelectric capacity and plans to expand the use of hydropower. In March 2003, a contract was awarded by the federal government for construction of the 750-megawatt El Cajón hydropower project, to be built in the northwest state of Nayarit at Tepic [*28*]. El Cajon is one of the largest public infrastructure projects undertaken by the Mexican government in several years, with completion scheduled for 2008.

Western Europe

Among the countries of Western Europe, mature electricity infrastructures and slow population growth are expected to translate into relatively slow growth in demand for electric power over the 24-year projection period. Western Europe's electricity demand is projected to increase by an average of 1.3 percent per year, from 2,246 billion kilowatthours in 2001 to 3,029 billion kilowatthours in 2025 (Figure 65).

The summer of 2003 was marked by several widespread power failures in some of the largest economies of the Western European region. An unusually severe heat wave occurred during the summer months, testing many nations' electricity infrastructures. Nuclear power plants were forced to curb operations in Germany and in France when water temperatures exceeded legal limits

Figure 65. Net Electricity Consumption in Western Europe, 2001-2025



Sources: **2001:** Energy Information Administration (EIA), calculated by the Office of Integrated Analysis and Forecasting, based on estimates of fuel inputs for electricity generation and assumed average generation efficiencies by fuel type. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

and the nuclear power plants could not dispose of the water used to cool nuclear core elements. In addition, a lack of wind resulted in weaker performance of installed wind generation in Germany.

In August 2003, London experienced an electric power outage that affected 400,000 customers during rush hour [*29*]. However, the U.K. natural gas and power market regulator, Ofgem, determined that the failure—and another one that followed a week later—were not caused by insufficient grid investment. Instead, the outage was caused by the wrong type of fuse installed on backup protection equipment. In September 2003, a power failure caused by falling tree limbs cut off power to 55 million people in Italy for 18 hours, attributed, at least in part, to the slow reaction of ETRANS (the Swiss firm that coordinates participation in Europe's grid) to inform Italian grid operator Gestore della Rete di Trasmissione [*30*]. Denmark and Sweden, with integrated electricity systems, suffered their worst blackout in 20 years when the 1,135-megawatt nuclear power plant at Oskarshamn in Sweden was shut down, triggering an automatic closure at Sweden's 1,800 megawatt Ringhals nuclear power plant [*31*]. The shutdown at Oskarshamn was attributed to a fault on the transmission line. Lack of investment in the Scandinavian power grid has been cited as a key reason for the massive failure.

The number and severity of the power failures that hit Western Europe in 2003 have raised concerns about the liberalization of electricity markets in the region. In the case of the United Kingdom, Sweden, and Denmark, governments are questioning whether the power failures resulted from a lack of investment in the national grids, which is less profitable to companies than is investment in new capacity. In Italy, on the other hand, the government has moved to speed up the process of liberalization in the wake of the widespread power outages, by expediting legislation on an energy reform bill that would make it easier for companies to construct new generation capacity [*32*]. In the short term, the government passed an emergency decree at the end of August 2003 that allowed the Industry Ministry to let power producers ignore temperature limits on the waters they discharge [*33*].

The EU, after many years of negotiation, passed directives in 2003 that establish deadlines for opening electricity and natural gas markets. The directives require that markets for nonresidential consumers be opened to competition by July 2004 and for all consumers throughout the EU by July 2007 [*34*]. The directives also require the separation of distribution wires from other parts of the electricity industry and the institution of energy sector regulators. The directives are not expected to result in radical shifts in EU electricity markets in the near term.

The 2003 EU directives on electricity and natural gas follow from the original 1996 agreement that began forcing EU member countries to open their electricity markets for competition [*35*]. The market opening imposed rules upon member countries according to a timetable that allowed each country to define its own pace of market liberalization, somewhere between the European Commission minimum requirements and full immediate opening. Introducing competition into the EU markets was expected to result in increased energy efficiency and lower prices for consumers.

In the countries that have instituted mandated opening of their electricity markets as a result of the 1996 agreement, customer prices have generally declined. In Germany, wholesale and retail competition opened in 1999, and power prices in 2000 were around 26 percent lower than in 1995. Residential sector power prices fell by 8 percent, even with the additional costs of the country's ecological tax and laws supporting renewable energy use and combined heat and power (CHP) [*36*]. In the United Kingdom, electricity prices for industrial and commercial consumers fell by between 20 and 25 percent from October 1998 to 2003 [*37*].

Markets in Spain began opening to competition in 1999, and although the terms of the EU directive on electricity required only that one-third of Spain's total electricity sales be liberalized by 2003, the country has already surpassed this requirement [*38*]. Between 1996 and 2001, electricity prices fell by 29 percent in real terms, primarily due to reductions in tariffs rather than as a result of competition in the electricity sector.

France has been the slowest in liberalizing its electricity markets. It has opened 30 percent of its electricity market to competition, but only 5 percent of the country's power companies have third-party access agreements. Further, state-owned Electricité de France (EdF) supplies 87 percent of all French electricity demand today and owns the entire national grid, making competition difficult [*39*]. In January 2004, however, the French Commission de Regulation de l'Energie announced that French electricity (and natural gas) distributors must start testing their computer systems by April 2004 in preparation for open retail markets [*40*]. Commercial and industrial customers are scheduled to be able to pick their electricity suppliers by July 2005 and residential customers by 2007.

Liberalization and the commitments of EU member countries to enact policies aimed at reducing greenhouse gases, as specified under the Kyoto Protocol, are expected to have an impact on the fuel mix for electricity generation in Western Europe. Oil is expected to become less important to the mix, particularly in countries where it has historically been high, notably Italy. Natural gas—with its efficiency and environmental advantages over other fossil fuels—is projected to gain share throughout the region, as is renewable energy, given widespread government programs to support its expansion. Coal is expected to continue to lose market share in Western Europe, as it has for much of the past decade.

With plans for uprates and extending the operating lives of many nuclear reactors, nuclear power generation is projected to increase somewhat over the next decade, but planned retirements and few plans for new generating units are projected to reduce the potential for nuclear power after 2010. As a result, electricity generation from nuclear power is expected to decline precipitously from 2010 to 2025. Finland and France are the only Western European countries expected to construct new nuclear power plants in the *IEO2004* reference case. Other European countries are expected to begin to retire nuclear capacity by the end of the forecast. Both Belgium and Germany have passed laws that require their nuclear power plants to be phased out.

Electricity generation from renewable energy sources other than hydroelectricity (which is already substantially developed in the countries with appropriate resources) is expected to continue fast-paced growth among the countries of Western Europe. The governments in the region offer support for nonhydropower renewable power sources, most notably wind, in the form of subsidies or requirements that utilities purchase a certain amount of power from "green" energy sources. Germany, Spain, and Denmark remain the fastest growing wind producers in the world, and the United Kingdom, Ireland, and Portugal all are experiencing a surge in installed wind capacity.

In 2003, Ireland's Airtricity began installation of the first phase of the 25.2-megawatt Arklow wind farm [*41*]. The $59 million project, located 6.3 miles off Ireland's east coast. consists of seven 3.6-megawatt turbines. It is scheduled to begin generating electricity by the end of 2004. Airtricity has proposed to eventually expand the site to up to 200 turbines, making it the largest offshore wind project in the world.

Portugal had about 200 megawatts of installed wind capacity at the beginning of 2003, and its wind capacity is expected to more than double to 450 megawatts before 2008 [*42*]. Two new facilities are projected to begin operation in 2004, one at Lomba da Seixa II near the northern Portuguese cities of Braga, Vila Real, and Porto, and one at Senhora da Vitoria in the central western part of the country near Nazaré. They will add a combined 24 megawatts of wind power to the grid of Portugal's largest utility, Electricidade de Portugal.

Germany

In Germany, there has been a shift away from coal-fired generation since the reunification of the country in 1990.

Coal use for electricity generation fell from 3.5 quadrillion Btu in 1990 to 2.6 quadrillion Btu in 2001, largely reflecting the reduction in coal use in the eastern half of the country. This trend is expected to continue over the projection period, as natural gas and renewable energy resources displace the use of coal for electricity. Nuclear power is expected to be phased out in Germany, in accordance with German law that retires reactors after an average lifespan of 32 years. No new nuclear units are expected to be built in Germany as a result of the government's commitment to phase out nuclear power.

Germany remains one of the fastest-growing markets for wind power, setting national and world records for the installation of wind capacity in the past several years. German energy policy has set a target of doubling the renewable share of total energy use between 2001 and 2006, according to the Erneuerbare Energien Gesetz (Renewable Energies Act) of 2000 [***43***]. In early 2003, the German government announced it would extend the target deadline to 2010, and it would also extend the deadline for installing subsidized offshore wind power to 2010 [***44***]. The government has announced its goal to install 500 megawatts of offshore wind capacity by 2006 and 3,000 megawatts of offshore wind capacity by 2010. In 2002, wind power accounted for 4.7 percent of Germany's total electricity generation, up from 3.0 percent in 2001. The German Electricity Feed-In Law has helped support the increase in wind power by requiring utilities to purchase renewable-generated electricity at above-market rates [***45***].

France

France remains heavily reliant on nuclear power for its electricity generation, and this is expected to remain the case throughout the forecast period. Nearly 80 percent of France's electricity consumption is attributed to nuclear power, and although its share is projected to fall slightly from 2001 to 2025, nuclear clearly will dominate the French electricity market for years to come. In the *IEO2004* reference case projection, few French nuclear reactors are expected to be retired over the forecast period, and two new reactors are expected to be built. Further, the operating lives of most reactors are expected to be increased to 50 years, and significant capacity uprates are expected.

Natural gas use for electricity generation in France is projected to grow substantially in the forecast, while renewable energy use remains fairly flat. The French National Assembly passed an electricity feed-in law in 2001 that guarantees wind power producers reimbursement of about 9.8 cents per kilowatthour during the first 5 years of operation [***46***]. At present, France has 185 megawatts of installed wind capacity, including a 20-megawatt wind facility that began operating in June 2003 at Pays de la Loire, about 28 miles south of Nantes on the Atlantic coast.

United Kingdom

In the United Kingdom, coal is the dominant fuel source for electricity generation, at 37 percent of total energy use for electricity generation in 2001, followed by natural gas at 28 percent of the total. The mix is projected to shift so that, in 2025, natural gas will be the dominant resource in the U.K. electricity market. Coal's share is projected to drop precipitously as gas use climbs. Oil's role in the U.K. electricity market has been declining steadily over the past several decades and contributes very little to electricity generation in the *IEO2004* forecast.

Nuclear power currently accounts for about 23 percent of the United Kingdom's electric power supply. In the mid-term future, however, 8,879 megawatts of installed nuclear capacity is expected to be lost by 2025, as nuclear power reactors are shut down and no new reactors are expected to replace them. British Energy has had difficulty competing in the deregulated environment of the U.K. electricity market, supporting the expectation of a decline in nuclear power (see box on page 115). The United Kingdom has not ruled out future expansion of its nuclear industry, however, and government policies that affect the costs of fossil fuels in the future could help to bolster the U.K. nuclear program.

On April 1, 2002, the Renewables Obligation, which requires licensed electricity suppliers to provide a specific portion of their total electricity sales from eligible renewable sources, became law in the United Kingdom [***47***]. The government estimates that the law will provide around $1.8 billion in support for the U.K. renewable industry. The British government passed legislation in 2003 that set a target to generate 10 percent of the country's electricity from renewable energy sources by 2010 and 20 percent by 2020 [***48***]. In addition, the legislation required that the Renewables Obligation percentage be increased to 15 percent by 2015. This is expected to have a profound impact on the installation of wind capacity over the mid-term. Although in the past it has been difficult to site wind facilities because of considerable local resistance, the Crown Estate (which controls British public lands) awarded leasing rights of up to 50 years for 15 wind sites in December 2003 [***49***]. The electricity from these projects is expected to begin flowing in 2007. When completed, it is expected to provide up to 7,000 megawatts of electric capacity. At the end of 2002, the United Kingdom had 552 megawatts of installed wind capacity.

Italy

In Italy, oil has been an important source of energy for electric power generation over the past several decades. With the opening of the country's electricity markets to competition, this is expected to change. If the government is successful in passing legislation that would expedite the liberalization of Italian energy markets,

Deregulated Electric Power Markets and Operating Nuclear Power Plants: The Case of British Energy

One issue addressed in almost all electric power restructuring or deregulation plans in both the United States and the United Kingdom was the recovery of spent fuel disposal costs for operating nuclear power plants and the expenditures to decommission the units when they are retired—costs that are often called "back-end liabilities." Before restructuring, in theory at least, electricity consumers in both countries were made to pay for the back-end costs for operating nuclear power plants. Moreover, in virtually all cases in the United States, individual States included special provisions to ensure that consumers would continue to do so after power markets were deregulated. Indeed, this is probably one reason why operating U.S. nuclear power plants could be sold to firms selling power in deregulated markets and operated profitably.

In contrast to the United States, however, when power markets in the United Kingdom were deregulated, the issues associated with back-end costs were more difficult. Because of a unique set of circumstances, to ensure that operating nuclear power plants would remain viable in deregulated electric power markets, the U.K. government (as opposed to electricity consumers and/or utility shareholders) had to take responsibility for the payment of many of the back-end liabilities.

In 1988, the U.K. government decided to both privatize the electricity generation and transmission industry and create a "competitive" generation market. However, partly because of the concerns about decommissioning and poor operation of some of U.K. nuclear units, the decision was made to keep all the country's nuclear power plants, which generated about 20 percent of its electricity, in the public sector. The decision was revisited in 1995, when the government decided to privatize its newer advanced gas cooled (AGC) reactors and one light-water nuclear power plant.[a] Thus, a company called British Energy (BE) was formed. The total capacity of all the power plants owned by BE was about 9.6 gigawatts, all of which was nuclear.

In mid-July 1996, the government "transferred" ownership of BE to the private sector by selling about 700 million shares of BE stock on the open market. The initial selling price of the stock was about 240 pence per share, and the sale netted about 1.7 billion pounds. In the first few years after the privatization, BE's stock price increased, peaking at more than 700 pence in early 1999. Share prices then fell, and from 2000 to early 2002 BE's stock traded in the range of 200 to 300 pence. Then, in 2002, serious financial problems arose, and the government intervened with financial assistance in order to forestall bankruptcy. As of early 2004, BE's stock price was 5 to 10 pence per share.

To explain BE's financial problems and the government's response, two general points must be made. First, the bulk of a nuclear power plant's operating costs are fixed, in the sense that they will be incurred even if the plant is not operating. This is partly due to the need to operate and maintain a nuclear plant's safety systems even if the unit is not generating electricity. As a result of the fixed nature of the operating costs, profits are sensitive to prices—that is, a 10-percent change in prices will result in almost a 10-percent change in profits. Second, the British reprocess the spent fuel from their gas-cooled nuclear power plants; and as a result, BE had contracts with British Nuclear Fuels Limited (BNFL) for services dealing with the handling of the spent fuel. The contracted costs of these services, as reported in the media, are about 300 million pounds per year, or about 5 pounds per megawatthour of plant output.[b] In the United States, where nuclear waste is not reprocessed, spent fuel disposal costs collected from consumers are equivalent to 0.67 pounds per megawatthour.[c]

In the first few years after the privatization, BE's nuclear plants were indeed profitable, in the sense that the revenues from sales were greater than the operating costs (see table on page 116). Over the 1997-1999 period, BE's return on equity was about 10 to 12 percent, and it had healthy positive cash flows. The cash was used to purchase a large coal-fired power plant and interests in nuclear units in Canada and the United States.[d] In 2000, however, the British restructured the wholesale electric power market in England and Wales, and shortly thereafter electricity prices began to fall. By the end of 2001, wholesale electricity prices had fallen by about 30 percent. Because many nuclear operating costs are fixed, the best way to decrease costs is to increase productivity—that is, become more efficient. BE was able to reduce costs by about 15 percent, but not

(continued on page 116)

[a]The British also owned about 5 gigawatts of very old and very small gas-cooled nuclear power plants, often called Magnox reactors. They were kept in the public sector, and currently about 50 percent of them have been retired. In all probability, the remaining ones will be retired by 2010.

[b]S. Thomas, "The Collapse of British Energy: The True Cost of Nuclear Power or a British Failure?" (University of Greenwich, July 2003).

[c]An exchange rate of 1 pound to 1.5 dollars was used to convert the 1 mill per kilowatthour charge.

[d]BE acquired a long-term lease for a number of Canadian nuclear units and thus, in a technical sense, was not a partial owner of the plants.

Deregulated Electric Power Markets and Operating Nuclear Power Plants (Continued)

sufficiently to offset the decreases in revenues. As a result, BE lost money in 2001.

As electricity prices continued to fall in 2002-2003, BE incurred some serious liquidity problems and needed inflows of cash to remain solvent. The company was having difficulty obtaining credit from private lenders and was unable to renegotiate its contracts with BNFL. On September 9, 2002, BE borrowed about 400 million pounds from the British government. Initially, the loan was to be repaid by the end of the month. On September 26, 2002, however, the loan was extended to November 29, 2002, and the amount was increased to 650 million pounds. At that point it also became apparent that BE's financial problems were not limited to a short-term lack of liquidity. In fact, from March 2002 through February 2003, BE lost about 4,300 million pounds, which included a one-time writedown of its generating plants, at about 3,700 million pounds. Thus, BE and the U.K. government began discussions about the longer term restructuring of the company. The discussions dealt with a number of longer term issues, the most important of which were related to back-end liabilities.

In late November 2002, the government announced a complex plan to restructure BE. As part of the plan, the government agreed to extend the loans though September 2004, and BE obtained an agreement from its major creditors to freeze interest and loan repayments. BE's creditors also agreed to forgive substantial amounts of its debt, partly in exchange for receiving new stock in BE. The savings to BE have been estimated at about 750 million pounds. To generate cash, BE also agreed to sell its shares in U.S. and Canadian nuclear plants. The sales were finalized in late 2003, for which BE received about 950 million pounds.[e]

The most controversial part of BE's restructuring plan dealt with back-end liabilities. Before the new agreement, BE was liable for all of the spent fuel reprocessing and disposal costs, plus the expenses to decommission its plants. Under the restructuring plan, the U.K. government assumed responsibility for all the costs of handling, storing, and disposing of the waste generated by the gas-cooled reactors in the past, as well as some of the back-end costs for waste generated in the future. The European Commission estimated that the present value of the costs incurred by the government over the next 80 years would be more than 3 billion pounds—an amount that is 5 times the 2003 book value of BE's power plants.[f]

BE still would be responsible for most of the costs of reprocessing and disposing of the waste generated in the future and for the decommissioning of its power plants. Many of those activities will be funded from a large trust owned by BE; that is, monies would be contributed into the trust and invested in stocks and bonds, and payments for many of BE's back-end obligations would come out of the trust. The restructuring plan requires that BE contribute to the trust 65 percent of its cash remaining after taxes and interest and dividend payments. Typically, without this requirement, the funds would be used to obtain productive assets,

(continued on page 117)

Operating Costs and Revenues of British Energy's Nuclear Power Plants

Year	Output (Terawatthours)	Operating Costs (Pounds per Megawatthour)	Total Operating Costs (Million Pounds)	Average Selling Price (Pounds per Megawatthour)	Total Revenues (Million Pounds)
1997-98	66.7	19.8	1,321	26.3	1,754
1998-99	69.1	19.9	1,375	24.6	1,700
1999-2000 . .	63.0	19.9	1,254	25.7	1,619
2000-01	63.5	18.7	1,187	21.7	1,378
2001-02	67.6	16.7	1,125	20.4	1,379
2002-03	63.8	17.6	1,126	18.3	1,168
2003	33.2	15.3	508	15.8	525

Note: The data for 2003 cover the April-September period. BE's fiscal year runs from March through February. Thus, for example, the data for 2000-2001 cover the period March 2000 to March 2001. Also, the data do not include BE's non-nuclear costs or revenues, interest expenses, or overhead costs.

Sources: S. Thomas, "The Collapse of British Energy: The True Cost of Nuclear Power or a British Failure?" (University of Greenwich, July 2003); and British Energy, *2003 Interim Annual Report*.

[e]British Energy, *Interim 2003 Annual Report* (December 2003).

[f]"State Aid—United Kingdom: Invitation To Submit Comments Pursuant to Article 88(2) of the EC Treaty, Concerning Aid C 52/03 (ex NN 45/03)—Restructuring Aid in Favour of British Energy plc," *Official Journal of the European Union*, C 180/5 (July 31, 2003).

Deregulated Electric Power Markets and Operating Nuclear Power Plants (Continued)

such as additional power plants. Thus the requirement limits the potential for future growth of BE.

The restructuring plan currently is being reviewed by the European Commission and, therefore, has not been fully implemented.[g] In BE's *2003 Annual Report*, it presented both its regular balance sheet and one based on the assumption that the restructuring plan was fully in effect as of that date. The table below reproduces the latter balance sheet in a slightly different form. Note that BE's short- and long-term nuclear back-end liabilities add up to 4,199 million pounds.[h]

British Energy's Balance Sheet as of March 31, 2003, If the UK Restructuring Plan Were in Effect
(Million Pounds)

Assets	Total Fixed Assets	625
	Nuclear Liabilities Trust Fund	334
	Government Assumption of Back-End Costs	3,865
	Other Current Assets	1,080
	Total Assets	5,904
Liabilities	Short-term Borrowing and Creditors	362
	Short-Term Nuclear Back-End Liabilities	176
	Other	233
	Total Short term Liabilities	771
	Long-Term Debt	762
	Long-Term Nuclear Back-End Liabilities	4,023
	Total Liabilities	5,556
Total Equity		348

Source: British Energy, *2002/2003 Annual Report*, pp. 13-14.

About 334 million pounds of the back-end liabilities will be covered by the trust, and the UK government will cover the remaining 3,865 million pounds. The table also shows the importance of the UK government's assumption of some of the back-end liabilities. Without it, BE's liabilities would have been about 3.5 billion pounds greater than its assets. It is difficult to see how BE could remain viable under such circumstances.

In short, many of BE's financial problems were related to the reprocessing of the spent fuel from its gas-cooled reactors, an activity that even BE recently argued was not economical.[i] In "regulated" markets, it was easy to shift the costs of such activities to consumers. In deregulated markets, without some type of government intervention, the forces of competition can limit a firm's ability to recover such costs. This point was recognized by U.S. State and Federal authorities when they deregulated wholesale power markets. They explicitly decided to shift the costs of prudent but *ex post* uneconomical actions (dealing mainly with the construction of many nuclear power plants) to the current generation of consumers by means of "stranded cost recovery." In the United Kingdom, 15 years after a deregulated electric power market was created in England and Wales, the government finally decided to shift many of the back-end costs to present and future taxpayers.

[g]"State Aid—United Kingdom: Invitation To Submit Comments Pursuant to Article 88(2) of the EC Treaty, Concerning Aid C 52/03 (ex NN 45/03)—Restructuring Aid in Favour of British Energy plc," *Official Journal of the European Union*, C 180/5 (July 31, 2003).

[i]Note that nuclear liabilities are expressed in present value terms. Thus, if all the back-end costs were incurred today, they would total 4,199 million pounds.

[h]British Energy, "Nuclear Waste: British Energy's Views," submission of British Energy to the House of Commons: Environment, Food and Rural Affairs Committee (November 13, 2001).

natural gas use is expected to increase markedly, given its competitive advantages over oil. Italy relies on imported electricity to meet nearly one-fifth of its domestic electricity demand. The Italian government is concerned about improving its domestic electricity supply for energy security reasons and is expected to promote the use of natural-gas-fired generation, as opposed to oil-fired generation that would increase the country's reliance on Middle Eastern oil imports.

Renewable energy sources are also expected to grow in importance. The Italian government has set a goal of doubling electricity production from hydropower and other renewable energy resources by 2012, which would add more than 7,000 megawatts of installed renewable electricity capacity [***50***]. In total, Italy has set a target to generate 25 percent of its electricity from renewable resources by 2010. While the *IEO2004* reference case projection does not expect this goal to be achieved, renewable generation in Italy is projected to double by 2025 from the 2001 level. In a 1987 referendum, Italy voted to stop the use of nuclear power. Although there are four inactive nuclear power reactors in the country, all of them are being dismantled, and there are no plans to resume the use of nuclear power.

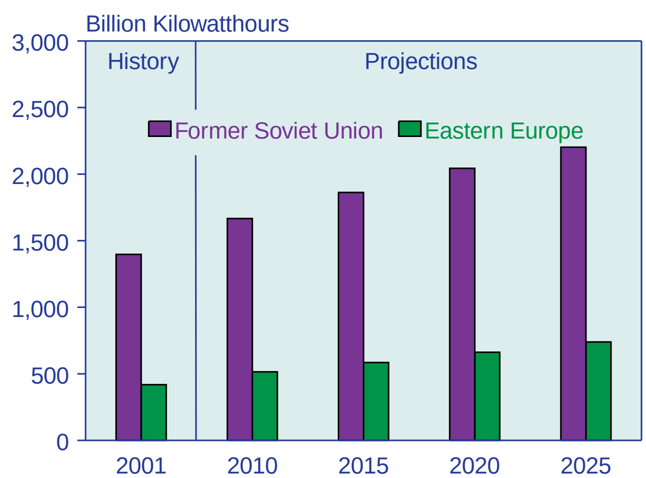
Former Soviet Union

The FSU region has had several years of positive economic growth, raising the demand for secure supplies of electric power. Electricity demand is projected to continue to grow in the FSU, by an average of 2.0 percent per year from 2001 to 2010 and another 1.9 percent per year from 2010 to 2025, reaching 2,202 billion kilowatthours per year in 2025 from the 2001 level of 1,397 billion kilowatthours (Figure 66).

Electricity generation from fossil fuels, mostly natural gas and coal, dominates the electric power sector in most of the countries of the region where resources are available, and its on natural gas and coal is expected to increase over the projection period. Nuclear power and oil-fired generation are expected to become less important while renewable energy sources retain their shares of electric power supply. Four countries in the region—Armenia, Lithuania, Russia, and Ukraine—currently generate a portion of their electric power with nuclear generators. Lithuania generates nearly 80 percent of its electricity from its two Iglanina nuclear power reactors. Much of the increase in renewable energy use in the FSU region is expected to involve the refurbishment, repair, or expansion of existing sites that fell into neglect under the Soviet regime, rather than construction of new, greenfield projects.

The FSU countries are increasingly looking toward western electricity markets as models for reform. In Russia, for example, the electricity market is expected to be fully deregulated by 2006 [***51***]. In 2003, the Russian government opened a new wholesale spot market, where electricity can be traded at free market prices. Initially, electricity trade on the new exchange is limited to between 5 and 15 percent of a generator's total output. Furthermore, purchasers of electricity are limited to supplying no more than 30 percent of their electricity needs

Figure 66. Net Electricity Consumption in Eastern Europe and the Former Soviet Union, 2001-2025



Sources: **2001:** Energy Information Administration (EIA), calculated by the Office of Integrated Analysis and Forecasting, based on estimates of fuel inputs for electricity generation and assumed average generation efficiencies by fuel type. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

from the deregulated exchange and must purchase the rest from Russia's regulated power market, Forem.

Russia's Unified Energy System (UES), the state-majority-owned electric utility, has submitted a draft plan to the Russian government for improving the infrastructure of the country's electric power sector. The investment plan requests about $953 million for 2004, and a final ruling on the proposal was expected by the end of November 2003 [***52***]. Even if approved, the proposal falls short of the total investment of $55 billion that UES estimates will be needed over the next decade to ensure the operation of the Russian power sector [***53***]. Plans to privatize and overhaul the Russian electric power sector are aimed at gaining private and foreign investment in the sector over the longer term.

Additional Russian reforms to the electricity sector include the privatization of 10 new generating companies formed from UES, which now owns some 70 percent of the total Russian electricity market, as well as the creation of an independent high-voltage transmission system operator. The transmission system operator would remain under government control, as would all hydroelectric power generators, until at least 2008. The country's nuclear power generating capacity is expected to remain under state ownership for the foreseeable future. However, five new electricity generating companies that own fossil-fuel-fired power plants are scheduled to be privatized by 2006.

The Russian electricity fuel mix remains heavily dependent on natural gas. According to an estimate by Cambridge Energy Research Associates (CERA), the gas share of total thermal generation exceeds 60 percent, largely encouraged by many years of price capping [***54***]. Coal and oil use for electricity has declined over the past decade. The Russian government is concerned about over-reliance on natural gas and has proposed increasing investment in nuclear power and hydroelectricity. The country has also recognized the need to expand and enhance its transmission grid. There are plans to interconnect the Siberian, European, and Far Eastern Russian power systems.

The Russian government has proposed doubling the amount of energy generated by nuclear power before 2020 and plans to construct 40 new nuclear reactors by 2030. The first unit at Rostov nuclear power plant—the first nuclear power reactor to be completed in Russia since the fall of the Soviet Union—came on line in early 2001. Another reactor, the 1,000-megawatt Kalinin unit 3 is scheduled for completion by the end of 2004. Although the *IEO2004* reference case does not reflect the fast-paced development of nuclear power that the Russian government has announced, several new units are projected to become operational over the forecast period. As a result, no decline in Russia's electricity production from nuclear power is expected until after 2015.

As in most of the other FSU nations, Russia's expansion of hydroelectric resources is expected, in part, to be accomplished by the upgrading and repair of existing facilities. For instance, the St. Petersburg-based utility Lenenergo is planning to refurbish three of its hydroelectric plants, Narva, Lesogorsk, and Svetogorsk [*55*]. The Narva hydroelectric plant, located near the Russian-Estonian border, would be used to export electricity to Estonia. Narva began operating in 1955 and has never had a major overhaul of its generating capacity; Lenenergo has estimated that the refurbishment of the plant would cost about $17 million and would take 8 years to complete. The Lesogorsk and Svetogorsk plants are located at the Finnish border and have been in almost continuous service since 1945. Most of the electricity generated at the two plants, which have a combined installed capacity of 192 megawatts, is exported to Finland. An overhaul of the plants will cost an estimated $52 million.

There has been some progress in constructing new hydroelectric capacity in Russia, and the 2,000-megawatt Bureya hydroelectric plant began operating in Russia in June 2003 [*56*]. The plant, located in the Russian Far East, is expected to alleviate the frequent blackouts and high power prices that consumers in the region have been experiencing for the past several years. Power shortages were responsible for a number of deaths in the winter of 2000-2001 and are widely believed to have been the impetus for the recent electricity sector reform.

There are efforts to introduce some nonhydropower renewable energy projects in Russia, as well as in other FSU countries, particularly in niche areas that cannot be served by national transmission grids. For example, the European Bank for Reconstruction and Development is funding a feasibility study to add substantial wind power in the Chukotka region of northeastern Russia [*57*]. The project consists of the construction of 14 wind hybrid projects with a total installed capacity of 34.4 megawatts. The wind turbines would be provided with backup supply systems using diesel generators, fuel cells, or other suitable power sources. Chukotskenergo, the local power utility, has already installed and is successfully operating seven wind turbines with a total installed capacity of 2.5 megawatts, under a federal scheme introduced to reduce central government fuel subsidies. The power needs of the coastal area currently are met by diesel generators located in each of the region's scattered ethnic settlements, serving mines and various isolated industrial centers. An interconnected power supply system, which would be needed to minimize the reserve capacity requirements, was never developed because of the arctic climate, large distances, and limited road links between settlements.

Outside Russia, electricity sector reform has progressed, though with mixed success. Kazakhstan appears to be in the most advanced stage of restructuring in the region. Restructuring of the power sector in Kazakhstan began in 1995 with the unbundling of distribution, transmission, and generation functions [*58*]. By 1998, the government had privatized most of the country's generating capacity, as well as a number of distribution companies, and was allowing direct electricity sales to large end users. Ukraine also began privatizing its regional electricity distribution companies in 1995, but the process has moved slowly, and most of the country's 27 distribution companies still are state-owned. In early 2004, the Ukraine State Property Fund canceled plans to sell its stakes in five regional power utilities, citing opposition to the current administration [*59*].

Nuclear generation remains an important part of the Ukrainian supply mix. In December 2000, the Ukrainian government permanently shut down operations at the 925-megawatt Chernobyl unit 3 plant, the last operating plant at Chernobyl. Although many analysts believe that Ukraine has surplus electric capacity, the government still is working to complete two nuclear power plants begun under the Soviet Union, the Khmelnitsky-2 and Rivne-4 reactors [*60*]. In September 2003, the Ukrainian government announced that it would finish construction of the reactors without financing from the European Bank of Reconstruction and Development, which had repeatedly refused to make a decision to approve a loan for this purpose.

In Lithuania, two electricity distributors, Vakaru Skirstomieji Tinklai (VST) and Rytu Skirstomieji Tinklai (RST) are in the process of being privatized [*61*]. In July 2003, the government announced plans to sell the majority stake in the two distributors, with hopes that the offer would earn more than $261 million for the country. Germany's E.ON, France's EDF, Russia's UES, Finland's Fortum, the U.S. company AES, Poland's Polskie Sieci Elektroenergetyczne (PSE), and NDZ Energija of Lithuania all have expressed interest in purchasing the two Lithuanian power distributors.

Azerbaijan's 1998 Law on Electricity provides a framework by which the state-owned electric company, Azerenerji, will be unbundled, along with the liberalization of the country's generation and distribution companies [*62*]. The Azerbaijan government approved the restructuring of Azerenerji in early 2002, and privatization is expected to progress, albeit slowly. Uzbekistan also approved a program for the partial privatization of the electric power sector in 2001, but again progress has been slow. In Turkmenistan, the electric power sector remains fully under state control.

Eastern Europe

With the accession of five key Eastern European economies (the Czech Republic, Hungary, Poland, Slovakia, and Slovenia) to the EU in May 2004 and Bulgaria and

Romania scheduled to join in 2007, Eastern Europe as a whole is restructuring and liberalizing its electricity markets to adhere to EU requirements. This will likely mean a switch from coal- to natural-gas-fired generation and, in several instances, has required acceding nations to release timetables for the dismantling of nuclear power reactors that the EU considers unsafe by western standards. In the *IEO2004* reference case, net electricity consumption in Eastern Europe is projected to increase by 2.4 percent per year on average, from 418 billion kilowatthours in 2001 to 739 billion kilowatthours in 2025. Coal's share of the total energy consumed for electricity generation is projected to fall from nearly 60 percent in 2001 to 44 percent in 2010 and 24 percent in 2025. In contrast, the natural gas share of total generation is expected to increase rapidly, from 10 percent in 2001 to 48 percent in 2025. Oil and nuclear power are projected to lose share in the region's power sector, and the renewable share of electricity generation is projected to grow from 13 to 14 percent.

Hungary's electric power sector already has been largely privatized. Electricity supplies are provided by 12 power generating companies distributed by 6 regional distribution and supply companies [*63*]. About 40 percent of the country's electricity is provided by the 4-unit PAKS nuclear power project and the rest from fossil fuels. The EU has inspected the PAKS units and determined that they are as safe as western nuclear reactors and in compliance with EU standards. The units were originally planned to have a 30-year lifespan, which is likely to be extended to at least 40 years. Tightening environmental regulations are expected to lead to the replacement of Hungary's coal-fired plants with natural gas; and if plans proceed as expected, only one coal-fired plant, the 800-megawatt Matra plant (which provides about 13 percent of Hungary's electricity), will remain.

The Czech Republic has also opened its electricity markets; however, the state-owned electric power company Ceske Energeticke Zavody (CEZ) still provides nearly three-fourths of the country's electricity supply [*64*]. The Czech government owns 68 percent of CEZ, but the company is scheduled for privatization by 2006. Electricity markets are in the process of being opened to adhere with EU directives on deregulation. The Czech Republic is a member of the CENTREL system, which links the country's electricity grid to those of Poland, Hungary, and Slovakia. It is also an associate member of the Union for the Coordination of Transmission of Electricity (UTCE), which coordinates the operations of its 16 European transmitters in an effort to guarantee the security and synchronous operation of their power systems.

At present, coal is the most important component of the Czech Republic's power supply, although there are efforts aimed at reducing the country's dependence on coal, or at least improving the pollution controls associated with generating coal-fired electric power. Over the past 10 years, CEZ has implemented an aggressive environmental cleanup program that includes retrofitting flue gas desulfurization scrubbers on existing coal plants. By some estimates, the Czech coal-fired generators now operate more cleanly than some facilities in Western Europe [*65*].

In addition to environmental upgrades to existing coal facilities, the Czech Republic brought the 1,824-megawatt Temelin nuclear power plant into operation in 2001. This is an important new source of electric power for the country. Temelin and the country's other operating nuclear power reactor at Dukovany account for around 22 percent of the total Czech electricity supply. Temelin has been the source of dispute from some of the Czech Republic's neighbors, particularly Austria, where a petition demanding the closure of the plant was signed by 900,000 Austrians in January 2002, despite a September 2001 agreement between the Austrian and Czech governments that allowed the plant to begin operation [*66*].

Poland's electricity sector is even more reliant on coal-fired capacity than is the Czech Republic's, with coal accounting for more than 97 percent of its generation [*67*]. The dependence on coal is not expected to moderate substantially over the next decade, with few plans to introduce natural-gas-fired generation and no plans to introduce nuclear power. There are plans to begin to increase the amount of biomass and solid waste use for electricity generation, particularly biomass co-fired with coal.

Liberalization of Poland's electricity sector began in 1997 with the passage of the Energy Law Act of 1997 to meet the requirements for EU membership. Current plans would allow all electricity consumers to choose their own energy suppliers by the end of 2005 [*68*]. Third-party access to the national grid has already been granted to large electricity customers that consume at least 40,000 megawatthours per year.

The Polish electricity grid is already well integrated with those of its neighboring countries. Poland is a member of the CENTREL transmission system, which was connected to Western Europe's system in 1995, with 2,000 megawatts of capacity allowed through the system in both directions. Construction of a high-voltage power link between Poland and Lithuania began in 2001, with plans for completion by 2008.

Bulgaria's membership in the EU is under consideration for 2007, and the country is in the process of restructuring its electricity sector. In 1998, the Bulgarian parliament began liberalization of the country's power sector by unbundling the generation, transmission, and distribution activities of the state-owned power company, Natsional Elektricheska Kompania (NEK) [*69*]. In line with recommendations made by the International Monetary Fund, the unbundling was accomplished by the summer of 2000. In June 2003, 10 of the country's largest power-consuming companies were allowed to negotiate their electricity supplies and prices directly with generators. Also, as a precondition to EU membership, Bulgaria agreed to shut down four of its oldest nuclear reactors. At the end of December 2002, the country permanently shut down Kozloduy units 1 and 2, which the EU considered unsafe. Units 3 and 4 are scheduled for closure in 2008 and 2010. The Bulgarian government has announced plans to complete construction of the 1,000-megawatt Belene 1 and 2 nuclear power plants in an effort to compensate for installed capacity lost with the closure of the Kozloduy units [*70*].

The Bulgarian electricity sector is fairly diversified: 40 percent of the country's electricity is generated from nuclear power, 50 percent from fossil fuels, and 10 percent from hydropower. In addition, there have been some efforts to add alternative, nonhydropower renewable resources. A 20-turbine wind farm in northeastern Bulgaria, at Kavarna on the Black Sea, is expected to be completed by the end of 2004 [*71*]. It will be the country's first wind project. A second wind project in nearby Balchik is also under construction but has been delayed pending the results of an environmental inquiry into potential impacts on birds that migrate on the Via Pontica.

Bulgaria has been aggressively attempting to establish a regional power market. As the leading Balkan electricity producer, Bulgaria has ample installed capacity and has been an important source of electricity for its neighbors, having signed electricity supply contracts with Serbia, Montenegro, Albania, and Greece [*72*]. The heat wave and drought that created shortages in many countries of Central and Western Europe in the summer of 2003 helped to strengthen Bulgaria's role as an exporter of electric power. Romania's electricity distributor, Electrica, began negotiations with the Bulgarian state-owned power company, Natsional Elektricheska Kompania when the Cernavoda nuclear power plant was forced to shut down in August because of low water levels, removing 10 percent of Romania's generating capacity from service [*73*].

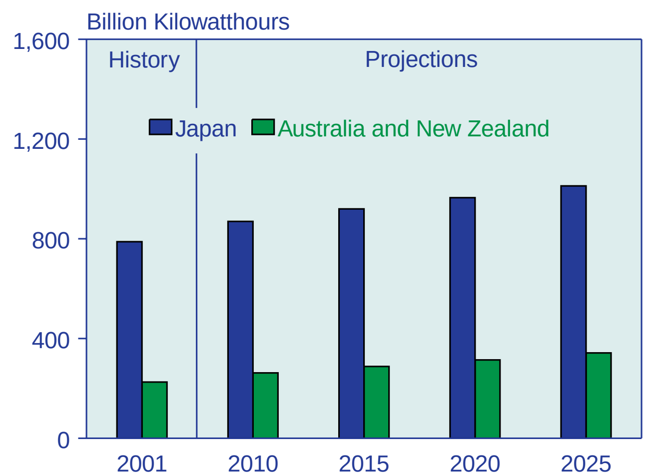
Industrialized Asia

The three countries of industrialized Asia (Japan, Australia, and New Zealand) all have mature electric power sectors. Japan has the region's largest installed electric capacity, at 235,000 megawatts, as compared with 43,000 megawatts in Australia and 9,000 megawatts in New Zealand. Net electricity consumption in the region is projected to grow by 1.2 percent per year on average, from 1,014 billion kilowatthours in 2001 to 1,354 billion kilowatthours in 2025. Australia and New Zealand combined are expected to see more rapid growth in electricity demand than Japan, where an aging population and the highest prices for residential electricity in the world are expected to result in only modest growth in the mid-term. Annual growth in Japan's electricity demand is projected to average only 1.0 percent over the forecast period, compared with 1.8 percent average annual growth projected for Australia and New Zealand (Figure 67).

The Japanese electric power sector is already privatized. However, 10 privately owned regional utilities produce 75 percent of the country's electricity and control the regional transmission and distribution infrastructure [*74*], discouraging competition from independent power producers and offering little incentive for price competition. With the lack of competition, strict government regulation, scarcity of indigenous natural resources, and high land and operating costs, Japanese electricity prices have remained high. The Japanese government has, however, begun the process of liberalizing electricity trading for large electricity consumers. The Electricity Utilities Law (passed in 1995) deregulated electricity retailing to large-scale consumers in March 2000. In April 2004, 18 companies will launch a wholesale electricity market, which will be opened only to large-scale industrial users.

Japan's electricity is produced largely from fossil fuels and nuclear power. In 2001, about 33 percent of its electricity was generated by nuclear power plants. A scandal hit the Japanese nuclear power industry in 2002, when it was disclosed that the country's largest nuclear

Figure 67. Net Electricity Consumption in Industrialized Asia, 2001-2025



Sources: **2001:** Energy Information Administration (EIA), calculated by the Office of Integrated Analysis and Forecasting, based on estimates of fuel inputs for electricity generation and assumed average generation efficiencies by fuel type. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

power company, Tokyo Electric Power Company (Tepco), had filed falsified inspection documents for 13 reactors [*75*]. At the end of 2002, in the aftermath of the scandal, Tepco was forced to suspend operations at a total of 17 nuclear power plants, only 7 of which had returned to operation as of March 2004. With the loss of such a substantial amount of capacity, more generation was switched to fossil fuels. According to the *Petroleum Intelligence Weekly*, a 2.2-percent increase in Japan's oil consumption in 2003 resulted almost entirely from an 18-percent increase in demand for fuel oil for electric power generation [*76*].

In spite of the recent problems in its nuclear power industry, Japan plans to build more nuclear capacity in the future and has announced plans to construct 13 nuclear power plants, with a combined capacity of 13,000 megawatts, by 2010 [*77*]. In the *IEO2004* reference case, Japan's nuclear capacity is projected to increase from 43,245 megawatts in 2001 to 56,882 megawatts in 2020 before declining to 54,281 megawatts in 2025 as several older units reach the end of their operating lives.

In recent years there has been increasing interest in the development of renewable energy resources in Japan, particularly wind and solar power. In April 2002, the Japanese government passed legislation for establishing a renewable portfolio standard [*78*], and by the end of the year installed wind capacity had reached 340 megawatts, well above the 1999 total of 20 megawatts. The government has set a target of installing 3,000 megawatts of wind capacity by 2010. Among the projects currently under construction is the 30-megawatt Rokkashomura wind project at Rokkashomura, on the eastern part of the Aomori Prefecture [*79*]. Upon completion, the project will be one of Japan's largest wind installations, providing power to the Tohuku Electric Power Company under a long-term contract.

Solar power has also advanced strongly in Japan, bolstered by government incentives and high residential electricity prices [*80*]. According to a study by CERA, demand for photovoltaics (PV) in Japan has grown by more than 40 percent per year over the past decade, from 19 megawatts in 1992 to nearly 860 megawatts at the end of 2003. With government incentives expected to continue to support the photovoltaic industry, solar power is likely to continue its fast-paced expansion. CERA has estimated that photovoltaic installations might reach as much as 7,000 megawatts by 2010.

In Australia, rich in domestic coal resources, almost 70 percent of electric power is generated from coal. Coal's share of electric power generation in Australia/New Zealand is projected to falls slightly in the *IEO2004* forecast, to 63 percent in 2025, and the natural gas share is projected to increases from 10 percent in 2001 to 19 percent in 2025, largely displacing oil and, to a lesser extent, coal.

Australia has been attempting to introduce competition in regional markets that already have an integrated transmission infrastructure. In 2001, the National Electricity Market announced that the states of Victoria, New South Wales, and Queensland had achieved a "fully contestable" power market, and plans are underway to extend competition to South Australia and Tasmania [*81*].

Although much of the growth in electric power markets is expected to be based on natural gas, Australia has also made several moves to increase the use of renewable energy. In 1997, the government established a Renewable Energy Equity Fund to provide capital for small renewable energy projects. The government's Renewable Energy Act, passed in 2000, requires power producers to increase the renewable share of their electricity mix by 2 percent by 2010 [*82*]. A total of 3,900 megawatts of renewable energy capacity is already under construction, including the 80.5-megawatt Lake Bonney wind project near Millicent in South Australia, which is scheduled to be completed by 2005 [*83*].

Developing Asia

The electricity sectors of the countries in developing Asia are expected to be the fastest-growing in the world. In the region as a whole, net electricity consumption is projected to increase at an average rate of 3.7 percent per year from 2001 to 2025 in the *IEO2004* reference case. In China alone, the projected average growth rate for electricity demand is 4.3 percent per year (Figure 68). Over the next two decades, electricity demand more than doubles in the *IEO2004* reference case, growing from 2,650 billion kilowatthours in 2001 to 6,274 billion kilowatthours in 2025. Much of the increase in demand is projected for the residential sector, where robust growth in personal income is expected to increase demand for newly purchased home appliances for air conditioning, refrigeration, cooking, and space and water heating.

China

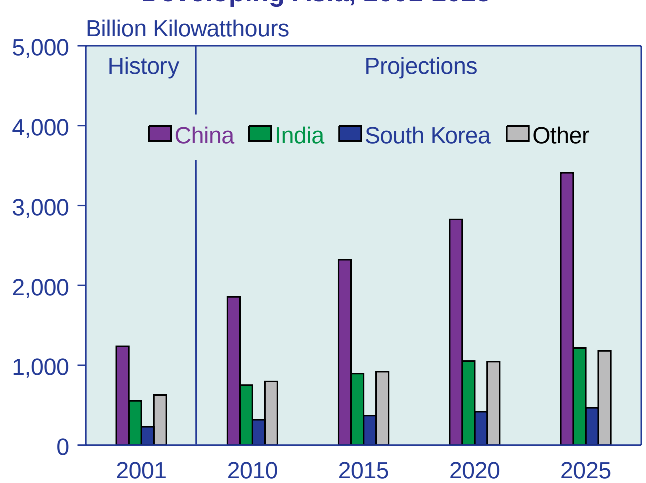
With high rates of annual GDP growth, electricity demand in China has grown substantially over the past decades. Over the past 5 years alone, China's net electricity consumption has grown by an average of 7.2 percent annually. Until recently China had a surplus of installed generating capacity as a result of the construction of power plants along the country's east coast during the 1990s [*84*]. Beginning in 1998, however, the Chinese government began trying to reduce the amount of surplus capacity by shutting down small, mostly coal-fired, power plants and discouraging new plant construction. A number of new plants were completed, however, and supply was largely able to keep up with demand until the past year or two. By some estimates, at the end of 2003 China was facing a deficit in capacity of more than 10 percent.

China's strong economic performance in 2003—fueling strong electricity demand in the industrial sector—and a particularly hot summer resulted in blackouts across the east and south portions of the country [*85*]. The problem was exacerbated further by low water levels, which reduced supplies of hydroelectric power in seven provinces [*86*]. There were some fears that the electricity shortage would worsen in the winter, and the Chinese government responded by requiring shopping centers and department stores in all major urban areas of the country to turn off their central heating for 2 hours each morning. In addition, large energy-consuming industries, such as steel, aluminum, and chemicals, were asked to shut down or operate only from 10 p.m. to 5 a.m., and peak power prices for residential consumers were raised fivefold in an effort to cut demand during the evening hours.

Because of the need to expand capacity to meet the strong growth in electricity demand, China has begun the process of restructuring to allow private investment in its electric power sector. In December 2002 the State Power Corporation was divided into five generating units and two transmission companies, with regulatory functions assigned to the China Electricity Regulatory Commission [*87*]. Although there have been efforts to introduce some privatization in the electric power sector, China's two largest privatized electric power generators, Huaneng Power and Beijing Datang Power, are still majority-owned by the government.

There have also been efforts to liberalize the electricity sector by introducing limited price competition. China began a simulated electricity price competition in early January 2004 as part of its effort to set up regional power markets. The government hopes that introducing price competition at the regional level will help to end provincial trading barriers and increase the reliability of supply. The northeast part of China was chosen for the test case, because it still has a power surplus and experience with a largely unsuccessful competitive pricing model in 1999. About 26 power generators, affiliated with 5 state-owned utilities in the northeast and eastern Inner Mongolia, began to sell power to distributors through a bidding process [*88*].

Figure 68. Net Electricity Consumption in Developing Asia, 2001-2025



Sources: **2001:** Energy Information Administration (EIA), calculated by the Office of Integrated Analysis and Forecasting, based on estimates of fuel inputs for electricity generation and assumed average generation efficiencies by fuel type. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

China's electric power fuel mix remains heavily reliant on coal; however, there are projects underway to increase hydropower, nuclear, and natural gas capacity, and their shares of electricity generation are expected to increase over the forecast period. Coal still is expected to remain the dominant fuel for electric power supply, with a projected 72-percent share of total energy use for electric power generation in 2025, compared with 76 percent in 2001.

China's 18,200-megawatt Three Gorges Dam project is scheduled to be fully operational in 2009, supplying 10 percent of current demand for electricity. In addition, China's Hydro Electric Corporation is presently developing 25 hydroelectric plants over a 570-mile portion of the Yellow River, which would add 15,800 megawatts of installed capacity. In addition, the 5,400-megawatt Longtan hydroelectric project on the Hongshui River is scheduled for completion in 2009 [*89*]. Plans have also been proposed for a 14,000-megawatt hydroelectric facility at Xiluodo and a 6,000-megawatt facility at Xiangjiaba.

There are also plans to increase China's nuclear power capacity. As of March 2004, nine nuclear reactors were operating in China, with a combined capacity of 6,199 megawatts. Two additional reactors are under construction, scheduled for completion before 2005. They will add another 2,000 megawatts of installed nuclear capacity [*90*]. The government is considering another 26 nuclear units for future development, with a total combined capacity of 23,000 megawatts, but it is unlikely that those units will become operational before 2025 [*91*]. The *IEO2004* reference case projects an increase in China's nuclear capacity of 18,626 megawatts from 2001 to 2025, reaching 20,793 megawatts at the end of the projection period.

China also has plans to construct six 320-megawatt natural-gas-fired generators in Guangdong province and to replace existing coal-fired capacity in Beijing with natural gas in time for the 2008 Olympics [*92*]. In light of growing electric power shortages, however, the government has begun to promote the construction of new coal-fired plants, along with the gas-fired facilities being constructed in Beijing, Shanghai, and a few other coastal cities [*93*]. Of the 30 new power projects approved for construction, most are coal-fired plants.

China remains concerned about improving rural electrification, and there are a number of renewable energy projects underway toward that end. Construction of the 150-megawatt Huitengxile wind power project in Inner Mongolia, is slated to begin in August 2004 [*94*]. Power generated by the wind project will be purchased by Inner Mongolia Electric Power Corporation, the regional utility based in Hohhot, and will be distributed through the electricity grid system to consumers throughout Inner Mongolia. Under the country's "Brightness Program," aimed at extending electrification to remote villages through solar-powered electricity, 78,000 rural households in Xinjiang province have already been supplied with solar modules, each with a capacity of 2.4 megawatts [*95*]. In December 2003, Shell Solar GmbH was awarded a contract by the Chinese government to supply another 26 villages in Yunnan and Xinjiang with solar-powered electricity.

India

Among the countries of developing Asia, India has the second largest installed electricity capacity, next to China's. India is expected to experience fast-paced growth in demand over the forecast, with strong economic growth of 5.2 percent per year projected between 2001 and 2025. Net electricity consumption is projected to grow by 3.3 percent per year, to 1,216 billion kilowatthours in 2025, more than double its 2001 level of 554 billion kilowatthours.

India is already running about an 8-percent deficiency in needed electricity supply. Increasing the capacity through foreign investment will be difficult, even though private investment in the electric power sector is allowed, because many foreign investors find the country's bureaucracy onerous. State electricity boards are in control of most of India's electricity sales and over half of the country's capacity [*96*]. There also are problems with distribution losses, caused in large part by theft, which has been estimated to be as high as 50 percent in New Delhi, Orissa, and Jammu-Kashimir. With federal and state governments unwilling to increase prices to improve service, extensive foreign investment in India's electricity sector is not expected in the short term.

India's electric power sector is dominated by coal, which accounts for 78 percent of its total generation. Hydroelectricity provides another 13 percent, and nuclear, oil, and natural gas provide the remainder. The government has plans to increase the use of hydroelectric, nuclear, and natural gas in the electric power sector over the mid-term. There are 13 nuclear power reactors operating in the country today, with a combined installed capacity of 2,460 megawatts. Another 8 reactors are currently under construction, and the government has set a goal of increasing the country's nuclear capacity to 20,000 megawatts by 2020 [*97*]. The *IEO2004* reference case projects total installed nuclear capacity in India of 8,923 megawatts in 2025.

The Indian government is pressing forward with aggressive plans to expand the country's hydroelectric capacity. In May 2003, the Indian Prime Minister Atal Bihari Vajpayee launched an initiative to add 50,000 megawatts of hydroelectric power by 2012 [*98*]. Several large-scale hydroelectric projects are under construction in India, including the 2,400-megawatt Tehri hydroelectric project. The first unit of the 1,500-megawatt hydroelectric project at Nathpa Jhakri was commissioned in October 2003 [*99*]. The Tehri project was scheduled for completion in mid-2003, but legal challenges delayed those plans [*100*].

There are also efforts to increase electricity imports to meet India's growing demand. In 2003, the government signed a memorandum of understanding to purchase hydropower from Bhutan's 870-megawatt Punatsangchhu project [*101*]. India also has plans to import electricity from the proposed 360-megawatt Mangdechhu project and 1,050-megawatt Tala project in Bhutan, both scheduled for completion in 2005. India also imports substantial amounts of electricity from hydroelectric projects in Nepal.

Other Developing Asia

In the other countries of developing Asia, including South Korea, demand for electricity is expected to grow by about 2.8 percent per year between 2001 and 2025, from 859 billion kilowatthours to 1,648 billion kilowatthours. About one-third of the region's electric power sector is fueled with coal, followed by natural gas (21 percent), oil (17 percent), and nuclear power and renewables (both about 14 percent). Over the projection period, natural gas and nuclear power are expected to gain shares of the electricity fuels mix, displacing mostly coal and, to a lesser extent, oil and hydropower.

South Korea's energy sector is well established, with a diversified fuel mix and adequate capacity to meet demand. Coal and nuclear power account for about 40 percent of generation each, and natural gas, diesel, and renewables account for the remainder. The South Korean government initiated restructuring and privatization of the electric power sector in 1993, when 8 percent of the state-owned Korea Electric Power Corporation (KEPCO) was offered for sale to foreign investors [*102*]. The country's restructuring plan included a gradual phase-in of liberalization, with wholesale competition not fully integrated until after 2009.

In contrast to South Korea's electricity sector, Indonesia's state-owned Perusahaan Listrik Negara (PLN) has had several difficult years. In the early 1990s, the Indonesian government signed contracts for 27 independent power projects, all of which were suspended during the country's 1998 economic crisis [***103***]. Although electricity demand has recovered from the crisis, which lasted through 1999, PLN has been unable to raise funds necessary to keep up with demand. Investors have been hesitant to return to the Indonesian market because of difficulties in resolving payment disputes in the wake of the economic collapse.

The Indonesian government enacted the Electricity Business Act in September 2002, in an effort to satisfy foreign investors' desire for reform in the sector. The legislation will eventually end the state monopoly over power generation and sales and will allow the separation of generation, transmission, and distribution functions [***104***]. According to the law, competition can begin any time after 2007.

Middle East

In the countries of the Middle East, high rates of population growth are expected to lead to rapid growth in demand for electricity over the next two decades. In the *IEO2004* reference case, net electricity consumption is projected to grow by 2.8 percent per year on average, from 476 billion kilowatthours in 2001 to 926 billion kilowatthours in 2025 (Figure 69).

For the countries of the region with large reserves of petroleum and natural gas, those fuels are expected to dominate electricity generation. The two largest regional electricity consumers, Saudi Arabia and Iran, use oil and natural gas to generate almost all their electricity. Turkey and Israel rely heavily on coal for their electric power supplies, although both countries also use substantial amounts of oil for electricity generation. Most of the major energy consumers in the region have plans to increase natural-gas-fired generating capacity over the forecast period. In Saudi Arabia, replacing oil-fired capacity with gas-fired capacity will allow the country to monetize their oil through export. In Turkey and Israel, adding gas-fired capacity is a way to diversify electricity supplies away from coal, and in Iran away from oil.

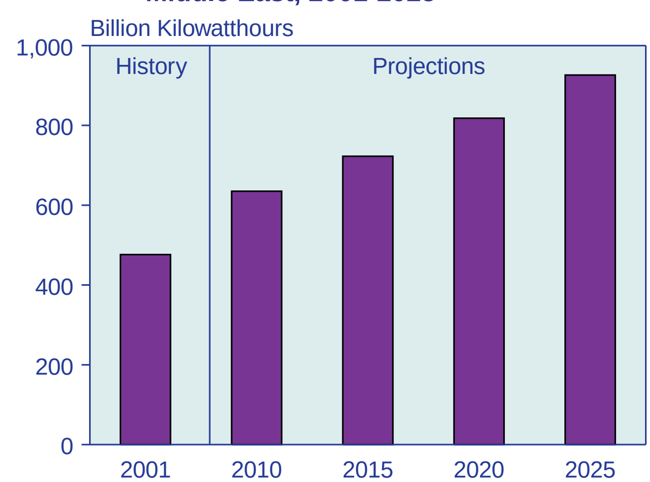
In many countries of the Middle East, the electric power sector is state-owned. Others have begun to consider opening their electricity markets in an effort to attract foreign investment. Saudi Arabia, for instance, began restructuring its electricity sector in the late 1990s, creating the Saudi Electricity Company (SEC) at the end of 1999 [***105***]. The SEC has been incorporated as a joint stock company, and the government has indicated that it will eventually lower its share of the company to 20 percent from 50 percent. There are plans to split the SEC into three divisions, separating generation, transmission, and distribution.

Saudi Arabia is also attempting to boost independent power development. In late 2003, construction began on the country's first independent power project, a 250-megawatt cogeneration plant being constructed in Jubail by U.S.-based CMS Energy and National Power Company (the latter a joint venture of Saudi Arabia's Al Jamil and El-Seif groups) for the Saudi Petrochemical Company [***106***]. The project is scheduled for completion in 2005, at which time CMS is expected to sell its 25-percent share of the project. At the end of 2003, the Saudi Electricity Company retendered three 2,000-megawatt power projects—at Shuaiba on the Saudi western coast and Ras al-Zour and Jubail on the Gulf—that were originally supposed to be part of the Saudi Gas Initiative.

The Saudi state-owned oil company, Saudi Aramco, has also begun efforts to increase power generation through independent power projects. In 2004, the company signed an agreement with U.K.-based International Power to build, own, operate and transfer some 1,074 megawatts of natural-gas-fired cogeneration capacity in the eastern part of Saudi Arabia. The project consists of constructing four plants to supply power to Saudi Aramco under four 20-year agreements. Saudi Aramco will provide the natural gas to the generators. Three of the plants—Ju'aymah, Shedgum, and Uthmaniyah—will have installed electric capacity of 308 megawatts and will produce 569 tons of steam per hour; the fourth, at Ras Tanura, will have an installed electric capacity of 150 megawatts, producing 293 tons of steam per hour.

In Iran, electricity demand grew at an average annual rate of around 8 percent from 1996 to 2001, and strong

Figure 69. Net Electricity Consumption in the Middle East, 2001-2025



Sources: **2001:** Energy Information Administration (EIA), calculated by the Office of Integrated Analysis and Forecasting, based on estimates of fuel inputs for electricity generation and assumed average generation efficiencies by fuel type. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

growth is expected to continue into the future. The Iranian government has set a goal of increasing capacity from 31 gigawatts in 2001 to 40 gigawatts in 2005 to meet the burgeoning demand [***107***]. Most of Iran's electric power is generated with natural gas, which accounts for about 80 percent of the total electric power fuel mix. The remainder is divided between hydropower and oil. The country also has a nuclear power reactor under construction, the 915-megawatt Bushehr 1 power plant, scheduled for completion in 2005.

Iran's electric power sector is regulated through the Energy Ministry's Power Generation and Transmission Management Organization (or TAVANIR) [***108***]. Sixteen regional power suppliers provide the country's generation and distribution. The Iranian government began the process of restructuring the electric power sector in 1998 in an attempt to attract foreign investment for power generation. Privatization of the power sector has moved slowly, however, and it is expected that TAVANIR will retain control over generation and distribution for the foreseeable future.

Iran's electricity fuel mix is likely to remain largely dependent on natural gas. Because the government would prefer to monetize its oil through exports, its plans for new fossil-fired capacity are centered exclusively on natural gas. There are also plans to increase the use of hydroelectric power in Iran, with a goal of adding 8,000 megawatts of new hydroelectric capacity by 2011. Both the environmental benefits of hydropower and the low costs of maintaining and generating electric power once construction has been completed make the energy source a particularly attractive one to the Iranian government.

In October 2003, Iran's largest hydroelectric power plant became operational. The 400-megawatt facility is part of the Karkheh dam project [***109***]. Other hydroelectric projects under various states of development include a 1,000-megawatt power station in Upper Gorvand, the 2,000-megawatt Godar-e Landar hydropower project, and the 3,000 megawatt Karun 3 plant [***110***].

Iran is also interested in importing electricity to help meet its growing power demand, particularly in the northeastern part of the country. In 2003, TAVANIR signed a $48 million contract to import electricity from Turkmenistan through a link-up of the two countries' electricity grids at the border towns of Meshhad, Serakhs, and Gonbad. When completed, the capacity of the transmission lines is expected to reach 700 megawatts. In May 2003, Turkmenistan agreed to export 640 million kilowatthours of power to Iran for the rest of 2003 for $12.8 million.

Electricity demand in the United Arab Emirates (UAE) has also been rapidly increasing in recent years. Between 1996 and 2001, electricity use in the UAE increased by nearly 9 percent per year. It is estimated that the UAE electricity sector will require about $8 billion in investment over the next 8 years to meet demand [***111***], and the government has plans to expand its 9,500 megawatts of installed capacity by more than 50 percent over the next decade.

The governments of the various emirates have chosen to handle their roles in the country's electric utility sectors in different ways. In Abu Dhabi, the electricity sector has been restructured by splitting the state-owned utility into private companies that separately handle generation, transmission, and distribution. The government will retain major stakes in the companies, with the Abu Dhabi Water and Electricity Authority serving as a regulatory body. Abu Dhabi has also attracted foreign investment in its electricity sector by allowing independent water and power projects, three of which are currently under development. Three emirate-owned utilities serve the electricity needs of the other emirates: the Dubai Electricity and Water Authority, the Sharjah Electricity and Water Authority, and the federal Ministry of Electricity and Water.

Turkey is another Middle Eastern country that will require extensive investment in its infrastructure if it is to meet future electricity demand. The country is expected to experience fast-paced population growth and healthy economic expansion in the mid term as it recovers from its economic recession of 2000-2001, accompanied by an increase in electricity demand.

Turkey is largely dependent on hydropower to meet its electricity needs, and 40 percent of its total installed capacity is hydroelectric [***112***]. A drought in 2001 underscored the need to diversify the electric power sector fuel mix. The country has been increasing its use of thermal generation, mostly in the form of natural gas and some coal, and it is expected to continue doing so in the mid-term. In the short term, generation from oil is expected to increase sharply to meet peak demand, because oil-fired generators can be built quickly with minimal infrastructure, compared to greenfield gas-fired power projects that require gas pipelines and other infrastructure.

Turkey's ample hydroelectric resources are expected to support an expansion of hydropower as well. The GAP hydroelectric and irrigation project in southeast Anatolia is currently under development. When completed, it will add some 7,500 megawatts of electric power capacity. Portions of the $32 billion project have already been completed, including the 2,400-megawatt Ataturk facility, the 1,800-megawatt Karakaya facility, and the 200-megawatt Batman and 200-megawatt Karkamis facilities. Power imports are also expected to play an increasing role in Turkey's electricity supply. At present, the country imports electric power from Russia, Iran, Bulgaria, and (for the first time in 2003) Turkmenistan. Imports from those countries are expected to continue increasing in the forecast [***113***].

The Turkish government has been keenly aware of the need to expand electricity and transmission capacity to meet demand. Efforts to bring new power projects into the country include build-own-transfer (BOT) projects in the mid-1980s and build-own-operate (BOO) projects in the mid-1990s. Efforts to restructure and liberalize the electric power sector culminated in the passage of the Electricity Market Law in February 2001 [***114***]. All of those efforts have had only limited success, however. The BOT agreements have encountered approval problems, mostly due to questions about their constitutional legality. In addition, because of Turkey's agreement with the International Monetary Fund to limit foreign debt in the wake of the 2000-2001 economic crisis, the Turkish government announced it would no longer be able to offer guarantees to finance BOT power projects. Finally, a corruption scandal at Turkiye Elektrik AS (TEAS) in early 2001 led to delays in the implementation of electric power sector reforms [***115***]. TEAS has since been separated into state-owned companies for electricity generation (Turkiye Elektrik Uretim AS), transmission (Turkiye Elektrik Iletim AS), distribution (Turkiye Elektrik Dagitim AS), and trading (Turkiye Elektrik Ticaret ve Taahhut AS).

Three of the BOO projects that were proposed in 1997 neared final approval at the end of 2003, but no schedule for their completion has been released. The three plants are a 777-megawatt plant at Adaparzi, a 1,524-megawatt plant at Izmir, and a 1,554-megawatt plant at Gebze. Their construction is expected to cost a combined $2 billion. The Turkish government is now promoting a Transfer of Operating Rights (TOR) model that would allow existing power plants to be licensed to private investors, in the hope that it will encourage efficiency upgrades. In June 2003, the Turkish Energy Ministry transferred 27 coal-fired and hydroelectric stations to the country's privatization agency, with the aim of completing privatization in 2004. Nineteen power distribution grids are also supposed to be privatized by the end of 2004 [***116***].

For some countries of the Middle East region, electricity theft is a major problem, with detrimental impacts on their efforts to attract much-needed foreign investment in electricity projects. In Lebanon, for example, efforts to draw foreign investment in the electricity sector included plans to privatize the country's electric utility Electricite du Liban (EdL). The plan originally anticipated that privatization would begin in 2003 with the sale of a 40-percent share of the utility; but those plans have been delayed indefinitely [***117***]. EdL is almost $3 billion in debt, and it costs the Lebanese Treasury about $200 million per year to purchase new fuel supplies. Electricity theft is the major cause of the problem, with a reported 25 percent of the electricity supplied by EdL per year being stolen by unauthorized taps on power cables.

The Lebanese government has also proposed raising electricity rates to attempt to reduce EdL's debt, but opponents argue that this would merely punish those customers who are already paying their electricity bills, without addressing the problem of theft. Moreover, even if the government were able to reduce electricity theft, the utility would continue to have financial difficulties because it is heavily reliant on oil-fired generation, and world oil prices have remained high. Alternative plans have included switching from oil to natural gas for generation electricity or for the country to participate in a power grid that supplies Jordan, Syria, Turkey, and Egypt.

Africa

For much of Africa, connecting populations to electric power supplies remains a primary goal. Problems with political corruption and a lack of transparency, domestic unrest and warfare in a number of countries, and the AIDS epidemic have strained the economies of many nations in the region. As a result, attracting investment into the region has been difficult. In many African countries, only a small percentage of the population has access to electricity. Nevertheless, efforts have continued in several countries, both to attract international investment in the electric power sector in general and to expand access to the power grid through rural electrification programs. In the *IEO2004* reference case, net electricity consumption in Africa more than doubles over the projection period, from 384 billion kilowatthours in 2001 to 808 billion kilowatthours in 2025 (Figure 70).

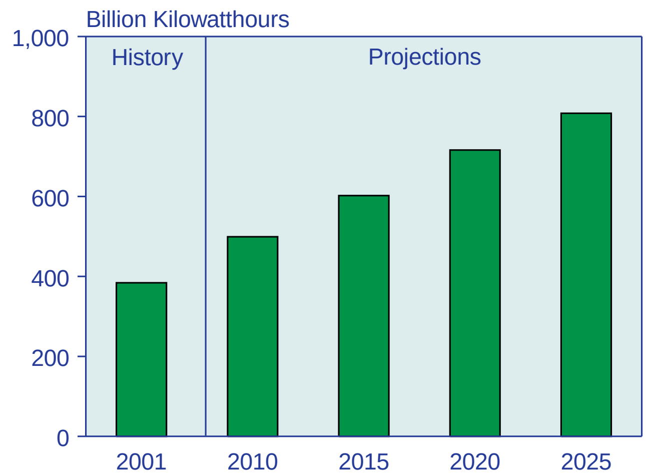
There is a move among some countries to initiate privatization in an effort to attract investment in the electric power sector infrastructure and help indebted state-run utilities become fiscally tenable. In Nigeria, the government has begun the process of restructuring its state-owned electric power company, the National Electric Power Authority (NEPA), by unbundling the utility into 18 separate companies, which are scheduled to be privatized. The government has estimated that some $1.4 billion would have to be invested in each of the companies to make the power sector reliable [***118***]. NEPA is already burdened with a debt of $3 billion in stranded costs making privatization essential for raising the needed funds. Privatization is scheduled to be completed by 2005.

The Nigerian electricity sector is dominated by thermal generation, mostly natural gas, followed by hydroelectric power. There are, however, efforts to introduce nonhydropower renewable energy sources. Renewable energy sources have proven to be a useful way to bring electricity to Africa's rural populations, especially in areas where difficult terrain makes it prohibitively expensive to extend national grids. In Nigeria, for instance, the first part of a $340,000 solar electrification project has been completed in several rural communities [***119***]. The project was initiated in conjunction with the U.S. Solar Electrification Fund (SELF) to assist rural communities in obtaining access to electricity. About $215,000 was expended on the pilot project, targeted at providing solar electric light to some designated areas at Wawar Rafi, Guru, Karaftai, and Maradawa villages. More communities are expected to benefit from the project.

South Africa has, by far, Africa's largest electric power sector, with 43 percent of the entire continent's total installed generating capacity in 2001. The state-owned electric power company Eskom generates nearly all of the country's electric power, with most of the generation produced by coal-fired power plants [***120***]. Eskom also runs the continent's only nuclear power reactor, the 1,930-megawatt Koeberg facility near Cape Town, and a small amount of hydroelectric power is also produced. Natural gas has only begun to be developed as a source of electric power. Gas supplies from Mozambique and Namibia are scheduled to begin flowing into South Africa over the next few years and may facilitate the growth in gas-fired electric power, particularly since Eskom has announced its intention not to construct any new coal-fired capacity.

The South African government is in the final stages of passing legislation on reform and restructuring of the country's electric power sector. A 30-percent share of Eskom is scheduled to be offered to investors by 2006 [***121***]. The government also plans to divest the company of its distribution assets, creating regional electric power distributors.

Figure 70. Net Electricity Consumption in Africa, 2001-2025



Sources: **2001:** Energy Information Administration (EIA), calculated by the Office of Integrated Analysis and Forecasting, based on estimates of fuel inputs for electricity generation and assumed average generation efficiencies by fuel type. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

With enough spare capacity to satisfy domestic demand until at least 2007, South Africa has become a major regional supplier of electric power [***122***]. The country already exports electricity to Botswana, Lesotho, Mozambique, Namibia, Swaziland, and Zimbabwe. South Africa is a member of the South African Power Pool (SAPP, established in 1995) along with Angola, Botswana, Congo (Kinshasa), Lesotho, Malawi, Mozambique, Namibia, Swaziland, Tanzania, and Zimbabwe [***123***]. The SAPP's aim is to integrate the South African power markets, thereby allowing utilities to reduce generation costs and provide reliable electricity supplies to the grids of member nations.

In September 2003, Zambia, Tanzania, and Kenya signed an agreement to construct an electricity grid that would unite the power grids of the three countries [***124***]. The $323 million project would help to enhance development of the SAPP, allowing power swaps and transfers among the three countries and the SAPP power networks, and improve the reliability of power supplies across southern Africa. Construction of the project is scheduled to begin in October 2004 and to be completed by the end of 2006.

After South Africa, Egypt has the second largest installed electricity capacity in Africa. About 80 percent of the country's electricity is from oil- or natural-gas-fired generators, with the remainder largely from hydroelectric power. Egypt plans to add substantial capacity through commissioned buy, own, operate, and transfer schemes within the next decade to meet rapidly growing demand. Much of the new capacity will consist of natural-gas-fired generators. In addition, expansion of the Zafarana wind farm to 600 megawatts is expected to be completed by 2010 [***125***].

The Egyptian government began the process of privatizing the country's electricity sector in 1998 by passing Law 18, which allowed the partial privatization of Egypt's Egyptian Electricity Holding Company and would allow investors to purchase up to 49 percent of the country's electric power generators [***126***]. The government is also encouraging private companies to construct electricity generating plants under buy, own, operate, and transfer agreements to make a more competitive electric power sector.

Ethiopia is a country where the population largely lacks access to the electric power grid. According to state-owned Ethiopian Electric Power Corporation (EEPCO), only 14 percent of the population is connected to the national power grid. In 2003, construction of the

180-megawatt Gilgel Gibe hydroelectric project in Ethiopia neared completion [*127*]. The plant has been under construction, off and on, since 1976. Upon completion, Gilgel Gibe will increase the country's total installed electric capacity to 600 megawatts—an increase of 43 percent. The facility will cost an estimated $247 million, funded by the World Bank, the European Investment Bank, and the Ethiopian government. Gilgel Gibe should help EEPCO reduce the electricity shortages it faced in 2003; however, the shortages were blamed largely on low rainfall, which could also affect Gilgel Gibe. Construction of another hydroelectric project, the $224 million, 300-megawatt Tekeze began in 2002 [*128*]. Tekeze, which is being constructed by a joint venture between EEPCO and the China National Water Resources and Hydropower Engineering Corporation, represents China's largest joint venture in Africa to date. Construction is supposed to be completed by 2007. When both Tekeze and Gilgel Gibe are completed, the two projects will significantly bolster EEPCO's plans to improve rural electrification [*129*].

Uganda is also attempting to improve electric power access. The Ugandan Energy Ministry has set a target date of 2012 to provide 10 percent of the country's population with access to electricity [*130*]. The government has estimated that an investment of at least $450 million will be needed to reach its goal. The country began privatization in an effort to attract foreign investment in its electric power sector, but talks with South Africa's Eskom have not progressed as scheduled, and Uganda may opt to re-tender its electricity services.

The economy of Zimbabwe has been struggling in the face of domestic political problems. The policies enacted by the Mugabe Administration—including the land redistribution program that has seized lands from white farmers and, in many cases, given them to supporters of the regime—have devastated domestic agricultural output. The country is currently facing a food shortage perpetuated by the redistribution program, as well as fuel and electricity shortages [*131*]. Zimbabwe imports substantial amounts of electricity from South Africa to help sustain its electricity sector, and in late January 2004 South Africa's Eskom cut power supplies for 2 days because of chronic nonpayment. At the same time, Mozambique reduced electricity supplies to Zimbabwe by 40 percent from 2003 levels [*132*]. In 2003, the Zimbabwe Electricity Supply Authority (ZESA) stated that it had signed a new agreement with the Congo to supply 100 megawatts of additional power capacity, added to the 150 megawatts of capacity it had already agreed to import [*133*].

Zimbabwe has begun the process of privatization, and two of the country's two major electric power generating plants, the Hwange and Kariba facilities, were being prepared for sale at the end of 2003 [*134*]. Two South African firms, Standard Corporate & Merchant Bank and Fieldstone Africa, were chosen as finalists to oversee the sale of the two facilities. ZESA is currently $200 million in debt and is hoping to gain $600 million by selling a 50-percent stake in each plant. Although the economic and domestic problems the country is still experiencing would make any investment in Zimbabwe risky, South Africa's Eskom has regional ambitions to dominate Africa's electricity network by obtaining generation assets.

Congo (Brazzaville) has a very small electric power sector, and virtually the entire electric power supply is from hydropower. The country has rich hydroelectric resources that have been largely underutilized, particularly after the sector was damaged during the country's civil war. There are, however, a number of hydroelectric power projects underway, including the 120-megawatt Imboulou project. Construction of the project, which is located on the Lefini River 133 miles north of Brazzaville, began in 2003 [*135*]. The $280 million facility is being built by Chinese companies CMEC and CIEMCO. Upon completion in 2009, it will provide power to Brazzaville and other cities in the northern part of the country and will double Congo's installed generating capacity.

Central and South America

Net electricity consumption among the nations of Central and South America is projected to grow by 3.2 percent per year in the *IEO2004* reference case projection, from 668 billion kilowatthours in 2001 to 1,425 billion kilowatthours in 2025 (Figure 71). The region relies heavily on renewable energy sources, largely hydroelectric power, to meet its electricity needs. Hydropower and other renewables account for nearly three-fourths of the total energy consumed for electricity generation in Central and South America today, and they are expected to be an important component of the region's fuel mix in the future; however, their share is projected to fall to 57 percent in 2025, giving up some of the market to natural gas.

As a result of their dependence on hydroelectric power, many nations of the region are concerned with diversification of their electric power fuel mixes. Low rainfall can have significant detrimental impacts on the region's ability to meet electricity demand. Most recently, drought in Brazil, the region's largest economy, in 2001 to 2002 resulted in brownouts and electricity rationing. In response to the crisis, Brazil pledged to increase thermal generation—especially natural-gas-fired units—in the country; however, when the drought ended and water levels returned to normal, many of the planned projects were suspended. Brazil, along with several other countries in the region, including oil-rich Venezuela, has plans to expand hydroelectric capacity over the next decade.

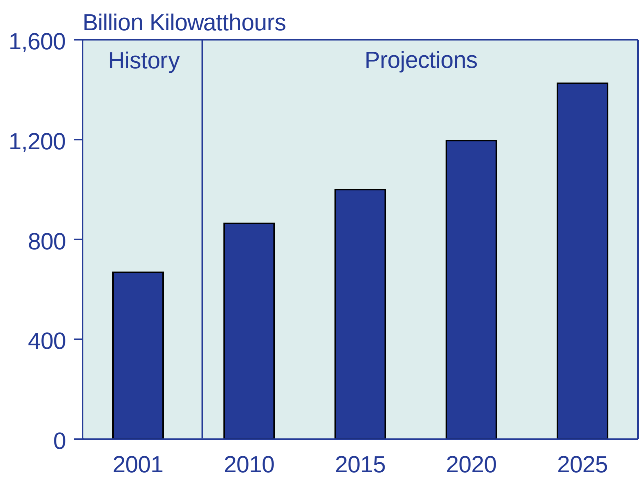
Another issue of importance to the countries of Central and South America is rural electrification. While the electricity infrastructures of many of the region's nations are adequate to supply urban areas, there are parts of the region that do not have access to national electricity grids. Programs aimed at increasing rural electrification to improve the standards of living of the population and allow productivity to improve are underway in several countries.

Brazil

The electricity shortages in Brazil in 2001-2002 that resulted from drought, economic crisis, and the election of Worker's Party president Lula de Silva, have resulted in the implementation of changes to the country's power sector. Restructuring and privatization of the electricity sector in Brazil was started under the Cardoso Administration in 1995. A wholesale electricity market, the Mercado Atacadista de Energia Elétrica (MAE) was established, and at present some 60 percent of electric power distribution is in the private sector.

The economic and energy troubles in Brazil in 2001-2002 were in large part responsible for slowing privatization efforts. Foreign investors were hesitant to make commitments to energy projects given the economic difficulties facing the country in the wake of the devaluation of the national currency, the real. The election of Lula de Silva, at least in the months immediately following, further dampened private investors' interest in entering the Brazilian market, because the Worker's Party was thought to be unfriendly to business.

Figure 71. Net Electricity Consumption in Central and South America, 2001-2025



Sources: **2001:** Energy Information Administration (EIA), calculated by the Office of Integrated Analysis and Forecasting, based on estimates of fuel inputs for electricity generation and assumed average generation efficiencies by fuel type. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

The Lula da Silva Administration has, however, made changes to the electricity sector that are expected to help improve security of the system and increase capacity. In September 2003, the government decided to provide a $1 billion aid package to Brazil's struggling electricity distribution companies [*136*]. The aim of the package is to help the companies reduce their short-term debt and allow them to resume investments in the sector. The government has also introduced legislation that would replace the MAE, which has performed poorly, with a new electricity pool and would allow independent power producers and large consumers to trade on a spot market [*137*]. The proposed legislation would also remove federally owned generators from the national privatization plan. The government believes that the removal of these generators from the privatization plan will make it easier to authorize increased investment by private companies [*138*]. Although the Brazilian Chamber of Deputies approved the government legislative proposals, the Senate postponed voting on the reforms in February 2004 [*139*].

Rural electrification is an important issue for Brazil. In November 2003, the Lula da Silva Administration announced a plan to invest $2.4 billion to provide electricity to 13 million people in rural areas of Brazil [*140*]. The "Light for All" project aims, in its first phase, to provide electricity to 7 million people by 2006. By 2008, 13 million Brazilians who do not currently have access to the national grid are expected to gain access as part of the plan. The program is expected to benefit states in the northeastern part of the country, which have the lowest levels of electrification in the country.

The plans for reform and rural electrification may increase opportunities for fossil-fired generators in Brazil, particularly natural gas. The country is concerned that a lack of investment in thermal power may result in electricity shortages over the next few years, as electricity demand growth—which declined after the shortages of 2001-2002—returns to normal. Under the terms of the electricity reform, distributors must contract for all their power needs, providing the guarantees necessary to finance thermal projects [*141*]. Because prices for thermal generation are somewhat higher than inexpensive hydroelectric prices, distributors would, in the past, look at the spot market for discounts when there was surplus hydroelectric capacity, making it impossible for thermal projects to compete effectively [*142*].

Along with the hopes for investment in thermal capacity in Brazil, there are also plans to expand hydroelectric capacity. The Brazilian government has announced that it anticipates the revival of 17 hydroelectric projects in 2004, with a combined installed capacity of 4,149 megawatts [*143*]. Brazil also has two operating nuclear power facilities, Angra 1 and Angra 2. The partially completed

Angra 3 unit is not expected to be completed in the *IEO2004* reference case forecast.

Argentina

Argentina, like many countries in Central and South America, began the process of restructuring and privatizing its electricity sector in the 1990s in order to attract foreign investment. In Argentina, the 1992 Energy Regulation Act established guidelines for restructuring and privatizing the country's electric power sector. With the exception of its two nuclear power plants, hydroelectric projects that are jointly owned with other countries, and some provincial utilities, most electricity companies in Argentina have been privatized.

The economic problems Argentina experienced in the early 2000s discouraged private investment in the country's electricity sector. The Argentine peso was devalued in January 2002, and the government ended the ability of utilities to peg their rates to the U.S. dollar, forcing them to bill clients in pesos. As a result, many companies were unable to meet their debt payments [***144***]. In addition, price controls on utility tariffs were frozen at pre-devaluation rates, and the Argentine government would not allow utilities to reduce their services. The tariffs have not been raised since January 2002, and utilities argue that the freeze has made it impossible for them to make needed investments in electricity infrastructure [***145***].

References

1. Energy Information Administration, *The Changing Structure of the Electric Power Industry: An Update*, DOE/EIA-0562(96) (Washington, DC, December 1996), p. 110.
2. P.J. Runci, *Energy R&D in the United Kingdom,* PNNL-13234 (Richland, WA: Pacific Northwest National Laboratory, March 2000), p. 11, web site http://energytrends.pnl.gov/uk/documents/uk.pdf.
3. Platts, "UK Lifts Ban on New Gas-Fired Power Plants" (November 15, 2000), web site www.platts.com/dereg/related_eu.shtml.
4. International Atomic Energy Agency, "Power Reactor Information System," Reference Data Series 2, web site www.iaea.org/programmes/a2/.
5. "KEDO Suspension Statement Shows Rift Over LWR Project" *Nucleonics Week*, Vol. 44, No. 48 (November 27, 2003).
6. International Atomic Energy Association, "Power Reactor Information System," web site www.iaea.org/programmes/a2/index.html (September 3, 2003).
7. E. Pianin, "Nevada Nuclear Waste Site Affirmed," *The Washington Post* (February 16, 2002), p. A1.
8. "Timeline: North Korea Nuclear Crisis," *BBC News: UK Edition*, web site news.bbc.co.uk (February 25, 2004).
9. "UN Pursues Atomic Warhead Trail," *BBC News: UK Edition*, web site news.bbc.co.uk (February 23, 2004).
10. "Bush, IAEA Propose Measures To Stop Nuclear Weapons Spread," *U.N. Wire* (February 12, 2004), web site www.unwire.org.
11. American Wind Energy Association, *Global Wind Energy Market Report* (Washington, DC, March 12, 2003), p. 1.
12. International Energy Agency, *World Energy Outlook 2002* (Paris, France, September 2002), p. 365, web site www.worldenergyoutlook.org/weo/pubs/weo2002/weo2002.asp.
13. "Portfolio Standards Blow Through North America," *North American Windpower* (March 2004), p. 9.
14. World Markets Research Centre, "Country Report—Canada (Energy) Electricity," (January 30, 2004), web site www.worldmarketsanalysis.com.
15. "Ontario Seeks Expedited Phaseout of Coal Power Plants," *Powerweek Canada* (January 26, 2004), pp. 1, 3.
16. Information supplied by Neil McIlveen, Natural Resources Canada (e-mail, February 25, 2004).
17. J. Shepherd, "Canada's Bruce A Unit Three Reconnected to Grid," *NucNet*, Vol. 4, No. 6 (January 10, 2004).
18. "Bruce Power Unit 3 Reactor Finally Back on Ontario Grid After Six-Year Closure," *Powerweek Canada* (January 12, 2004), pp. 1, 5.
19. "Ontario Seeks Expedited Phaseout of Coal Power Plants," *Powerweek Canada* (January 26, 2004), pp. 1, 3.
20. Electricity Conservation and Supply Task Force, *Tough Choices: Addressing Ontario's Power Needs, Final Report to the Minister* (Toronto, Ontario, January 2004), p. 55.
21. Electricity Conservation and Supply Task Force, *Tough Choices: Addressing Ontario's Power Needs, Final Report to the Minister* (Toronto, Ontario, January 2004), p. iv.
22. "Consultant Sees Ontario as Hot Market for Wind," *Restructuring Today* (October 16, 2003), p. 3.
23. "75-MW Canadian Wind Farm Complete," *Wind Energy Weekly*, Vol. 22, No. 1051 (July 11, 2003), electronic edition.
24. "Enmax, Vision Quest Open McBride Lake Wind Farm in Southern Alberta," *Solar and Renewable Energy Outlook*, Vol. 29, No. 28 (October 23, 2003), p. 238.

25. World Market Research Centre, "Canada: Suncor To Build New Canadian Wind Farm Project," (September 5, 2003), web site www.worldmarketsanalysis.com.

26. F. Vailles, "Énergie Éolienne; Une Demi-Douzaine de Promoteurs Ciblent la Gaspésie," *Le Soleil* (January 12, 2004), p. C2.

27. World Markets Research Centre, "Country Report—Mexico (Energy) Electricity" (January 21, 2004), web site www.worldmarketsanalysis.com.

28. "Ameco Awarded Contract To Support Construction of Mexican Hydro Plant," *Solar and Renewable Energy Outlook,* Vol. 29, No. 22 (September 8, 2003), p. 203.

29. "British Blackout Not From Lack of Money," *Restructuring Today* (October 2, 2003), p. 3.

30. "Europe Finds Waving Branches Probable Blackout Culprit," *Restructuring Today* (October 3, 2003), p. 3.

31. E. Yilmaz, "Western Europe Regional: Massive Blackout Hits Denmark and Sweden," *World Markets Analysis OnLine* (September 24, 2003), web site www.worldmarketanalysis.com.

32. E. Yilmaz, "Prospects for Power Sector Liberalisation After the Blackouts," *World Markets Analysis OnLine* (November 24, 2003), web site www.worldmarketsanalysis.com.

33. World Markets Research Centre, "Italy Passes Emergency Decree To Avert Widespread Blackout" (August 29, 2003), web site www.worldmarketsanalysis.com.

34. J. Chevalier and T. Le Quenven, *The European Gas and Power Industry Toward Maturity?* (Cambridge, MA, CERA Private Report: August 2003), p. 1.

35. J. Chevalier and T. Le Quenven, *The European Gas and Power Industry Toward Maturity?* (Cambridge, MA, CERA Private Report: August 2003), p. 4.

36. Global Insight, Inc., *European Energy Outlook: Volume I* (Lexington, MA, April 2003), p. 95.

37. Global Insight, Inc., *European Energy Outlook: Volume I* (Lexington, MA, April 2003), p. 256.

38. Energy Information Administration, *Country Analysis Briefs: Spain* (March 2003), web site www.eia.doe.gov.

39. Global Insight, Inc., *European Energy Outlook: Volume I* (Lexington, MA, April 2003), p. 53.

40. "France Gears up for Retail Competition," *Restructuring Today* (January 5, 2004), p. 1.

41. "GE Wind To Install 3.6-MW Turbines for Irish Project," *Wind Energy Weekly*, Vol. 22, No. 1047 (June 13, 2003), electronic edition.

42. "Enersis Taps GE Wind To Supply 16 Turbines, Construct Two Windfarms," *Solar and Renewable Energy Outlook*, Vol. 29, No. 27 (October 15, 2003), p. 231.

43. International Energy Agency, *IEA Wind Energy Annual Report 2002* (Boulder, CO: PWT Communications, April 2003), p. 113.

44. World Markets Research Centre, "Germany: Wind Power Deadline To Be Extended in Germany" (January 29, 2003), web site www.worldmarketsanalysis.com.

45. World Markets Research Centre, "Country Report—Germany (Electricity)" (December 4, 2003), web site www.worldmarketsanalysis.com.

46. "French Winds Tapped by New Turbines," *SolarAccess.com News* (June 18, 2003), web site www.solaraccess.com.

47. International Energy Agency, *IEA Wind Energy Annual Report 2002* (Boulder, CO: PWT Communications, April 2003), pp. 227-228.

48. J. Broehl, "UK Commits to 15 Percent Renewable Energy," *SolarAccess.com News* (December 2, 2003), web site www.solaraccess.com.

49. H. Timmons, "British Plan Major 'Wind Farm' To Generate Power Along Coasts," *The New York Times* (December 19, 2003), p. A6.

50. Energy Information Administration, "Italy: Environmental Issues," *Country Analysis Briefs* (December 2003), web site www.eia.doe.gov.

51. "Current: Russia Opens Its Electricity Market, Slowly and Gently," *World Gas Intelligence*, Vol. 14, No. 46 (November 12, 2003), p. 7.

52. World Markets Research Centre, "Russia: UES Plans US$953m Investment Programme for Russian Power Sector in 2004" (September 12, 2003), web site www.worldmarketsanalysis.com.

53. World Markets Research Centre, "Russia: France's EDF, Interros To Collaborate in Russian Energy Sector" (October 7, 2003), web site www.worldmarketsanalysis.com.

54. J. Webb et al., *Russia's Energy Strategy to 2020: An Incomplete Road Map* (Cambridge, MA: Cambridge Energy Research Associates Decision Brief, October 2003), p. 17.

55. "Lenenergo Seeks Hydro Investors," *Platts: Energy in East Europe*, No. 16 (June 13, 2003), p. 24.

56. World Markets Research Centre, "Russia: President Lights Up Russian Far East With Official Launch of Bureya Hydropower Plant" (July 10, 2003), web site www.worldmarketsanalysis.com.

57. "Study into Chukotka' Wind," *Platts: Energy in East Europe*, No. 17 (June 27, 2003), p. 20.

58. World Markets Research Centre, "Country Report—Kazakhstan (Energy) Electricity" (January 12, 2004), web site www.worldmarketsanalysis.com.
59. World Markets Research Centre, "Ukrainian State Property Fund Shelves Planned Sell-Off of Five Utilities in 2004" (January 12, 2004), web site www.worldmarketsanalysis.com.
60. World Markets Research Centre, "Ukraine: Tired of Waiting, Ukraine Plans To Finish K-2, R-4 Nuclear Plants Without EBRD Loans" (September 12, 2003), web site www.worldmarketsanalysis.com.
61. World Markets Research Centre, "Lithuania: Eesti Energia Plans To Participate in Lithuanian Power Distributor Privatisation" (September 5, 2003), web site www.worldmarketsanalysis.com.
62. World Markets Research Centre, "Country Report—Azerbaijan (Energy) Electricity" (January 15, 2004), web site www.worldmarketsanalysis.com.
63. Global Insight, Inc., *European Energy Outlook: Volume I* (Lexington, MA, April 2003), p. 45.
64. World Markets Research Centre, "Country Report—Czech Republic (Energy) Electricity" (December 1, 2003), web site www.worldmarketsanalysis.com.
65. Global Insight, Inc., *European Energy Outlook: Volume I* (Lexington, MA, April 2003), p. 9.
66. A. Kroeger, "Czech Nuclear Plant in Final Trial," *BBC News UK Edition* (April 18, 2003), web site www.news.bbc.co.uk.
67. World Markets Research Centre, "Country Report—Poland (Energy) Electricity" (December 22, 2003), web site www.worldmarketsanalysis.com.
68. Global Insight, Inc., *European Energy Outlook: Volume I* (Lexington, MA, April 2003), p. 82.
69. World Markets Research Centre, "Country Report—Bulgaria (Energy) Electricity" (January 22, 2004), web site www.worldmarketsanalysis.com.
70. World Markets Research Centre, "Bulgaria Entertains Offer on New Nuclear Power Plant at Belene" (January 14, 2004), web site www.worldmarketsanalysis.com.
71. "A Fair Wind for Yomi," *Platts: Energy in Eastern Europe*, No. 15 (May 30, 2003), p. 13.
72. "Boost for Bulgarian Electricity," *Emerging Market Monitor*, Vol. 9, No. 32 (December 1, 2003), p. 4.
73. World Markets Research Centre, "Romania: Romania in Talks With Bulgaria to Import Power Supplies" (September 5, 2003), web site www.worldmarketsanalysis.com.
74. World Markets Research Centre, "Country Report—Japan (Energy) Utilities: Electricity" (February 12, 2004), web site www.worldmarketsanalysis.com.
75. H.W. French, "Safety Problems at Japanese Reactors Begin To Erode Public's Faith in Nuclear Power," *The New York Times* (September 16, 2002), p. A8.
76. "What's New Around the World: Japan," *Petroleum Intelligence Weekly*, Vol. 43, No. 6 (February 9, 2004), p. 6.
77. "Current: Japan's Tepco Still Aiming for More Nuclear, Coal Use," *World Gas Intelligence,* Vol. 14, No. 48 (November 26, 2003), p. 7.
78. International Energy Agency, *IEA Wind Energy Annual Report 2002* (Boulder, CO: PWT Communications, April 2003), p. 151.
79. "GE Wind Makes Asian Sales," *Wind Energy Weekly*, Vol. 22, No. 1065 (October 17, 2003), electronic edition.
80. M. Rogol, *Tipping Point: Will Japan Become the First Mass Market for Solar Power?* (Cambridge, MA: Cambridge Energy Research Associates Decision Brief, February 2004).
81. World Markets Research Centre, "Country Report—Australia (Energy) Electricity" (October 13, 2003), web site www.worldmarketsanalysis.com.
82. International Energy Agency, *IEA Wind Energy Annual Report 2002* (Boulder, CO: PWT Communications, April 2003), p. 60.
83. SolarAccess.com, "Aussie Wind Project Receives Turbines," *Renewable Energy News* (July 7, 2003), web site http://solaraccess.com.
84. "China's Electricity Crisis Puts Coal Back in Fashion," *World Gas Intelligence.* Vol. 14, No. 50 (December 10, 2003), p. 7.
85. "Power Shortages 'Hit China'," *BBC News UK Edition* (July 18, 2003), web site www.bbc.co.uk.
86. "China's Electricity Crisis Puts Coal Back in Fashion," *World Gas Intelligence*, Vol. 14, No. 50 (December 10, 2003), p. 7.
87. World Markets Research Centre, "County Report—China (Energy) Electricity" (December 19, 2003), web site www.worldmarketsanalysis.com.
88. "China's Communist Leaders See Need for Power Competition," *Restructuring Today* (January 20, 2004), p. 3.
89. World Markets Research Centre, "County Report—China (Energy) Electricity" (December 19, 2003), web site www.worldmarketsanalysis.com.

90. International Atomic Energy Agency, "Power Reactor Information System," web site www.iaea.org/programmes/a2/index.html (no date).
91. Li Zhidong, *Present Situation and Mid- to Long-Term Outlook of Nuclear Power Development in China* (Tokyo: Institute of Energy Economics in Japan, July 2003).
92. World Markets Research Centre, "County Report—China (Energy) Electricity" (December 19, 2003), web site www.worldmarketsanalysis.com.
93. "China's Electricity Crisis Puts Coal Back in Fashion," *World Gas Intelligence.* Vol. XIV, No. 50 (December 10, 2003), p. 7.
94. "GE Wind Makes Asian Sales," *Wind Energy Weekly*, Vol. 22, No. 1065 (October 17, 2003), electronic edition.
95. SolarAccess.com, "Shell Solar Brings Solar Power to Rural China," (December 1, 2003), web site http://solaraccess.com.
96. World Markets Research Centre, "Country Report—India (Energy) Electricity" (December 31, 2003), web site www.worldmarketsanalysis.com.
97. World Markets Research Centre, "India: India Sets Targets for Nuclear Power Generation" (January 14, 2004), web site www.worldmarketsanalysis.com.
98. Press Trust of India, "PM Unveils Major Hydro Power Initiative" (May 24, 2003), web site www.rediff.com/money/2003/may/24power.htm.
99. B. Chauhan, "India's Largest Hydro Project Starts," *BBC News UK Edition* (October 14, 2003), web site news.bbc.co.uk.
100. "Indian Court Clears Dam Project," *BBC News UK Edition* (September 2, 2003), web site news.bbc.co.uk.
101. World Markets Research Centre, "Bhutan: India Signs New Agreement for Bhutanese Hydro Project" (September 15, 2003), web site www.worldmarketsanalysis.com.
102. Global Insight, Inc., *World Energy Service: Asia/Pacific Outlook 2002* (Lexington, MA, 2002), p. 279.
103. World Markets Research Centre, "Country Report—Indonesia (Energy) Electricity" (October 2, 2003), web site www.worldmarketsanalysis.com.
104. N. Semple and M. Hutchinson, "Indonesia Gas and Power: Working Together With the Government To Keep the Lights on in Java and Bali" (Cambridge, MA: Cambridge Energy Research Associates Decision Brief, July 2003), p. 12.
105. World Markets Research Centre, "Country Report: Saudi Arabia (Energy) Electricity" (October 15, 2003), web site www.worldmarketsanalysis.com.
106. "Saudi Arabia Jumps on Independent Power Bandwagon," *World Gas Intelligence*, Vol. 15, No. 1 (January 7, 2004).
107. World Markets Research Centre, "Iran: Iranian President Inaugurates Country's Largest Hydroelectric Power Plant" (October 8, 2003), web site www.worldmarketsanalysis.com.
108. World Markets Research Centre, "Country Report—Iran (Energy): Electricity" (January 8, 2004), web site www.worldmarketsanalysis.com.
109. World Markets Research Centre, "Iran: Iran Inks Contract to Import Turkmen Electricity" (September 5, 2003), web site www.worldmarketsanalysis.com.
110. World Markets Research Centre, "Country Report—Iran (Energy): Electricity" (January 8, 2004), web site www.worldmarketsanalysis.com.
111. World Markets Research Centre, "Country Report—UAE (Energy) Electricity" (September 16, 2003), web site www.worldmarketsanalysis.com.
112. Global Insight, Inc., *European Energy Outlook: Volume III* (Lexington, MA, April 2003), p. 212.
113. World Markets Research Centre, "Turkmenistan: Turkmens Export First Power to Turkey" (December 15, 2003), web site www.worldmarketsanalysis.com.
114. Global Insight, Inc., *European Energy Outlook: Volume III* (Lexington, MA, April 2003), pp. 210-211.
115. World Markets Research Centre, "Country Report—Turkey (Energy) Electricity" (September 12, 2003), web site www.worldmarketsanalysis.com.
116. World Markets Research Centre, "Turkey: Turkey Plans to Privatise Power Grids in 2004" (June 6, 2003), web site www.worldmarketsanalysis.com.
117. "Power Failure in Lebanon," *Emerging Markets Monitor*, Vol. 9, No. 20 (September 1, 2003), p. 18.
118. World Markets Research Centre, "Country Report—Nigeria (Energy) Electricity" (January 29, 2004), web site www.worldmarketsanalysis.com.
119. "Jigawa Finishes Phase One of Solar Electrification Project in Africa," *Solar and Renewable Energy Outlook*, Vol. 29, No. 16 (July 23, 2003), p. 166.
120. Eskom, "In the News: Reform Legislation Being Finalized for SA Power Sector" (January 28, 2004), web site www.eskom.co.za.
121. World Markets Research Centre, "Country Report—South Africa (Energy) Electricity" (January 16, 2004), web site www.worldmarketsanalysis.com.
122. World Markets Research Centre, "South Africa: Eskom Opens New SA Coal Plant" (September 15, 2003), web site www.worldmarketsanalysis.com.

123. Eskom, "The South African Power Pool" (September 23, 2002), web site www.eskom.co.za.

124. World Markets Research Centre, "Africa Regional: Zambia-Tanzania-Kenya Reach Agreement on Interconnection Link" (September 24, 2003), web site www.worldmarketsanalysis.com.

125. ArabicNews.com, "Egypt, Germany Sign Contract for Building Zafarana Power Station" (January 29, 2003), web site http://arabicnews.com/ansub/Daily/Day/030129/2003012929.html.

126. World Markets Research Centre, "Country Report—Egypt (Energy) Electricity" (February 4, 2004), web site www.worldmarketsanalysis.com.

127. World Markets Research Centre, "Ethiopia: New Ethiopian Hydropower Project to Come Online in October 2003" (July 23, 2003), web site www.worldmarketsanalysis.com.

128. Ethiopian Electric Power Corporation, "Power SDP; Program Summary," web site www.eepco.gov.et.

129. "Work Starts on Giant Ethiopian Dam," *BBC News World Edition* (August 12, 2002), web site www.news.bbc.co.uk.

130. World Markets Research Centre, "Uganda: Uganda Sets Rural Electrification Targets" (September 12, 2003), web site www.worldmarketsanalysis.com.

131. J. Scott-Joynt, "Long Wait for Zimbabwean Recovery," *BBC News UK Edition* (December 4, 2003), web site www.news.bbc.co.uk.

132. Eskom, "In the News: Eskom Cuts Off Supplies to Zim" (February 2, 2004), web site www.eskom.co.za.

133. World Markets Research Centre, "Zimbabwe Agrees New Power Supply Deal With DR Congo" (September 26, 2003), web site www.worldmarketsanalysis.com.

134. World Markets Research Centre, "Zimbabwe: Zimbabwean Electricity Asset Sell-Off Moving Forward." *World Markets Research Centre.* web site www.worldmarketsanalysis.com (November 17, 2003).

135. World Markets Research Centre, "Congo Begins Construction on 120MW Imboulou Dam" (September 26, 2003), web site www.worldmarketsanalysis.com.

136. "Brazilian Power Struggles," *Emerging Markets Monitor*, Vol. 9, No. 24 (October 13, 2003), p. 8.

137. L. Hornby, "New Brazil Energy Plan To Spur Thermal Invest," *The Oil Daily* (December 18, 2003), p. 4.

138. World Markets Research Centre, "Brazil's Chamber of Deputies Approves First Provisional Measure implementing New Power Sector Model" (January 29, 2004), web site www.worldmarketsanalysis.com.

139. World Markets Research Centre, "Brazilian Senate Postpones Voting on Electricity Reform Amidst Political Scandal" (February 18, 2004), web site www.worldmarketsanalysis.com.

140. "Brazil Expands Electricity Use," *The Oil Daily*, Vol. 53, No. 220 (November 13, 2003), p. 5.

141. L. Hornby, "New Brazil Energy Plan To Spur Thermal Invest," *The Oil Daily* (December 18, 2003), p. 4.

142. J. Waggoner, "Thermal Power Producers Want Details of Brazil Energy Plan," *The Oil Daily*, Vol. 53, No. 169 (September 4, 2003), p. 8.

143. World Markets Research Centre, "Brazil: Brazil's Federal Government Plans for 26 New Power Plants in 2004" (January 13, 2004), web site www.worldmarketsanalysis.com.

144. World Markets Research Centre, "Country Report—Argentina (Energy) Electricity" (February 5, 2004), web site www.worldmarketsanalysis.com.

145. World Markets Research Centre, "Argentine Capital's Mayor Slams Privatised Electricity Firms" (February 3, 2004), web site www.worldmarketsanalysis.com.

Environmental Issues and World Energy Use

In the coming decades, responses to environmental issues could affect patterns of energy use around the world. Actions to limit greenhouse gas emissions could alter the level and composition of energy-related carbon dioxide emissions by energy source.

Two major environmental issues, global climate change and local or regional air pollution, could affect energy use throughout the world in the coming decades. Current and future policies and regulations designed to limit energy-related emissions of airborne pollutants, are likely to affect the composition and growth of global energy use. Future policy actions to limit anthropogenic (human-caused) carbon dioxide emissions as a means of reducing the potential impacts of climate change could also have significant energy implications.

This chapter focuses on concerns about the local environmental and air quality impacts of mobile and stationary energy consumption, which have resulted in increasingly stringent regulation of air pollutants such as lead, sulfur oxides, nitrogen oxides,[16] particulate matter, and volatile organic compounds. Some countries are also considering ways to limit emissions of mercury from electric power generation to avoid the possible contamination of land surfaces, rivers, lakes, and oceans.

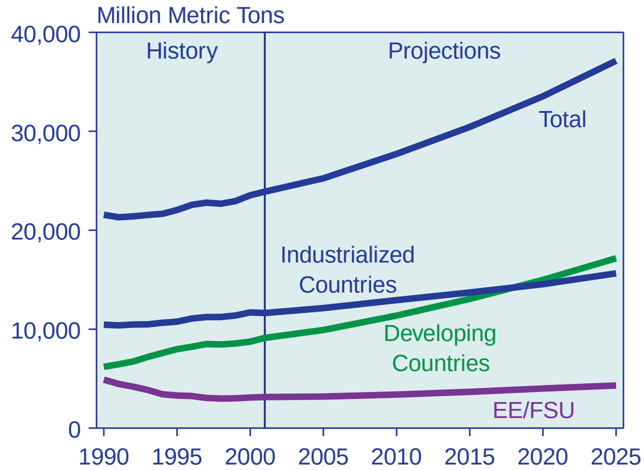
Global Outlook for Carbon Dioxide Emissions

The *International Energy Outlook 2004* (*IEO2004*) projects emissions of energy-related carbon dioxide, which, as noted above, account for the majority of global anthropogenic carbon dioxide emissions. Based on expectations of regional economic growth and dependence on fossil energy in the *IEO2004* reference case, global carbon dioxide emissions are expected to grow more rapidly over the projection period than they did during the 1990s. A projected increase in fossil fuel consumption, particularly in developing countries, is largely responsible for the expectation of fast-paced growth in carbon dioxide emissions. Because economic growth rates and population growth in the developing world are expected to be higher than in the industrialized world, accompanied by rising standards of living and fast-paced growth in energy-intensive industries, the developing nations account for the largest share of the projected increase in world energy use. Emissions are projected to grow most rapidly in China, the country expected to have the highest rate of growth in per capita income and fossil fuel use over the forecast period.

In 2001, carbon dioxide emissions from industrialized countries were 49 percent of the global total, followed by developing countries at 38 percent and the EE/FSU at 13 percent. In 2025, industrialized countries are projected to account for 42 percent of world carbon dioxide emissions, developing countries 46 percent, and the EE/FSU at 12 percent. The *IEO2004* projections suggest that carbon dioxide emissions from developing countries could surpass those from industrialized countries between 2015 and 2020 (Figure 72).

In the industrialized world, almost one-half of energy-related carbon dioxide emissions in 2001 came from oil use, followed by coal at 31 percent (Figure 73). Over the forecast period, oil is projected to remain the primary source of carbon dioxide emissions in industrialized

Figure 72. World Carbon Dioxide Emissions by Region, 1990-2025



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

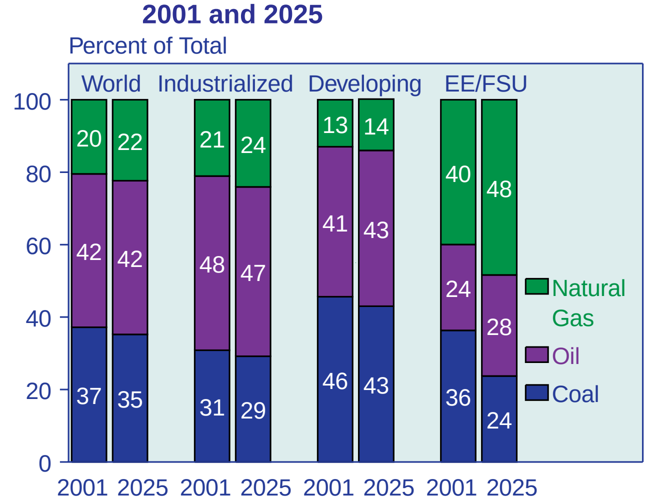
[16]Nitrogen oxides (NO_x) is the term used to describe the sum of nitric oxide (NO), nitrogen dioxide (NO_2), and other oxides of nitrogen that are short-lived atmospheric gases produced by the burning of fossil fuels and play a major role in the formation of ozone (smog). Nitrous oxide (N_2O), discussed later in this chapter, is a long-lived atmospheric gas produced primarily as a result of nitrogen fertilization of soils, mobile source combustion, and the decomposition of solid waste from domesticated animals. Nitrous oxide is also a greenhouse gas.

countries because of its continued importance in the transportation sector, where there are currently few economical alternatives. Natural gas use and associated emissions also are projected to increase, particularly for electricity generation. By 2025, the share of natural-gas-related emissions is expected to be 24 percent.

In the transitional economies of the EE/FSU region, 40 percent of energy-related carbon dioxide emissions comes from natural gas combustion. Coal production and consumption in the EE/FSU declined as a result of economic reforms and industry restructuring during the 1990s, bringing about an increase in the natural gas share of the energy and emissions mix during the period. Assuming the availability of sufficient capital for investment, further development of the vast natural gas reserves in Russia and the Caspian Sea region is expected to result in the continued displacement of coal by natural gas. Oil consumption is also projected to increase in the FSU, particularly for transportation and power generation, as Soviet-era nuclear reactors are retired in the coming years. As a result, both natural gas and oil are projected to account for increasing shares of the region's total carbon dioxide emissions, to 48 percent and 28 percent, respectively, in 2025.

With further restructuring of the coal mining industries in Poland and the Czech Republic, declines in coal production and consumption are expected to continue. Natural gas consumption is expected to double in Eastern European countries, in part because of the strict environmental standards required for membership in the European Union (EU). As a result of the projected changes in the energy mix, carbon dioxide intensity is expected to decline in Eastern Europe more than in any other region over the forecast period. Improvements in carbon dioxide intensity are expected to offset some of the growth in total energy consumption, but annual carbon dioxide emissions in Eastern Europe still are expected to increase by about 0.9 percent per year from 2001 to 2025.

Figure 73. Shares of World Carbon Dioxide Emissions by Region and Fuel Type, 2001 and 2025



Sources: **2001:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **2025:** EIA, System for the Analysis of Global Energy Markets (2004).

Compared with most of the industrialized countries, a much larger share of energy consumption in developing countries (particularly in Africa and Asia) comes from biomass, which includes wood, charcoal, animal waste, and agricultural residues (see box on page 140). Because data on biomass use in developing nations are often sparse or inadequate, *IEO2004* does not include the combustion of biomass fuels in its coverage of current or projected energy consumption, except for the United States; however, net emissions of carbon dioxide from biomass combustion are expected to be in balance in the long run with carbon sequestration by growing biomass and, therefore, are not included in the EIA estimates of greenhouse gas emissions.

Of the fossil fuels, oil and coal currently account for the majority of total energy-related carbon dioxide emissions in the developing world, and they are projected to remain the dominant sources of emissions throughout the forecast period. China and India are expected to continue to rely heavily on domestic coal supplies for electricity generation and industrial activities. Most other developing regions are expected to continue to depend on oil to meet the majority of their energy needs, especially in light of the projected increase in transportation energy demand.

Future levels of energy-related carbon dioxide emissions in many countries are likely to differ significantly from *IEO2004* projections if measures to mitigate greenhouse gas emissions are enacted, such as those outlined under the Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC). The Kyoto Protocol, which calls for limitations on greenhouse gas emissions (including carbon dioxide) for developed countries and some countries with economies in transition, could have profound effects on the future fuel use of countries that ratify the protocol. Because the Kyoto Protocol has not yet come into force, the *IEO2004* projections do not reflect the potential effects of the treaty or of any other proposed climate change policy measures.

Issues in Energy-Related Greenhouse Gas Emissions Policy

International Climate Change Negotiations

The global community's effort to address climate change has taken place largely under the auspices of the

UNFCCC, which was adopted in May 1992 at the first Earth Summit held in Rio de Janeiro, Brazil, and entered into force in March 1994. The ultimate objective of the UNFCCC is the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" [*1*]. The global community reaffirmed its commitment to the principles of the Framework Convention at the second Earth Summit held in Johannesburg, South Africa, in August 2002.

The implementation arm of the UNFCCC is the Kyoto Protocol, which was developed in December 1997 at the Third Conference of the Parties (COP-3). The terms of the Kyoto Protocol call for Annex I countries (including most of the industrialized countries) to reduce their overall greenhouse gas emissions by at least 5 percent below 1990 levels over the 2008 to 2012 period.[17] Quantified emissions reduction targets are differentiated by country (Table 17). The most recent COP meeting, COP-9, was held in Milan, Italy, in December 2003 (see box on page 144).

To achieve their emissions reduction targets, Annex I countries can implement domestic emission reduction measures or international "flexible mechanisms." The Kyoto Protocol includes the use of three "flexible mechanisms" (sometimes called "Kyoto mechanisms" or "market-based mechanisms") to help countries achieve their targets by allowing markets to determine the most cost-efficient way to reduce global greenhouse gas emissions.

- *International emissions trading* allows Annex I countries to transfer some of their allowable emissions to other Annex I countries, beginning in 2008, for the cost of an emission credit. For example, an Annex I country that reduces its 2010 greenhouse gas emissions level by 10 million metric tons carbon dioxide more than needed to meet its target level can sell the "surplus" emission reductions to other Annex I countries.
- *Joint implementation* (JI) allows Annex I countries, through governments or other legal entities, to invest in emission reduction or sink enhancement projects in other Annex I countries, gain credit for those "foreign" emissions reductions, and then apply the credits toward their own national emission reduction commitments.
- The *clean development mechanism* (CDM) is similar to joint implementation but the emissions reductions can occur in non-Annex I countries.

The Kyoto targets refer to overall greenhouse gas emission levels, which encompass emissions of carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. Hence, a country may opt for a small reduction of carbon dioxide emissions and a relatively greater reduction of other greenhouse gas emissions, or vice versa, in order to meet its Kyoto obligation. Currently, carbon dioxide emissions account for the majority of greenhouse gas emissions in most Annex I countries, followed by methane and nitrous oxide [**2**].

Different emissions may have notably different impacts on the atmosphere. Global warming potentials (GWPs) are used to compare the abilities of different greenhouse gases to trap heat in the atmosphere. GWPs are based on the radiative efficiency (heat-absorbing ability) of each gas relative to that of carbon dioxide. The IPCC is the generally accepted authority on GWPs for key greenhouse gases. In the latest IPCC assessment, published in 2001, the GWP of hydrofluorocarbon 23 is about 12,000 times that of carbon dioxide; thus, reducing emissions of hydrofluorocarbon 23 by a small amount would have a much larger impact than reducing emissions of carbon dioxide by the same amount.

The Kyoto Protocol will enter into force 90 days after it has been ratified by at least 55 Parties to the UNFCCC, including a representation of Annex I countries accounting for at least 55 percent of the total 1990 carbon dioxide emissions from the Annex I group. By the end of 2003, 119 countries and the European Union[18] had ratified the Protocol, including Canada, China, India, Japan, Mexico, New Zealand, and South Korea. A total of 31 Annex I countries, representing 44.2 percent of total 1990 carbon dioxide emissions, have signed on to the treaty (Figure 74) [*3*]. Two major Annex I countries, Australia and the United States, have announced that they will not adopt the Kyoto Protocol, leaving Russia as the deciding factor for entry into force. With its 17.4 percent of 1990 Annex I carbon dioxide emissions, Russia's ratification

[17] The Annex I nations include 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, the Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, and the United Kingdom. Turkey and Belarus, which are represented under Annex I of the UNFCCC, do not face quantified emission targets under the Kyoto Protocol. The Kyoto Protocol includes emission targets for 4 countries not listed under Annex I—namely, Croatia, Liechtenstein, Monaco, and Slovenia. Collectively, the 39 parties facing specific emissions targets under the Kyoto Protocol are commonly referred to as "Annex B parties," because their targets were specified in Annex B of the Protocol.

[18] Although the European Union (EU) ratified the Kyoto Protocol, the same group of countries was formally known as the European Community (EC) at the time the UNFCCC and Kyoto Protocol were written and is therefore referred to as the EC in most of the documents related to the UNFCCC and Kyoto Protocol.

Noncommercial Biomass Energy Use in Developing Countries

The International Energy Agency estimates that 14 percent of the energy consumed for end use throughout the world comes from noncommercial biomass fuels.[a] Noncommercial, or traditional, biomass consists mostly of solid fuels—wood, charcoal, agricultural residues, and wood and animal wastes—used in developing countries. An estimated 2.4 billion people in developing countries use biomass as their primary fuel for cooking and heating. Although more than half of the people who rely on biomass live in India and China (1.3 billion), the proportion of the population depending on biomass fuels is largest in Sub-Saharan Africa, where more than 85 percent of the population use biomass as their primary source of energy. In Latin America, only 23 percent of the population rely on biomass fuels for cooking and heating.[b]

Biomass fuels are less efficient for providing end-use energy services than are other fuels. For example, wood is less efficient than either kerosene or liquefied petroleum gas (LPG) for cooking. Although the use of biomass fuels can have negative effects on the environmental and, particularly, on human health, they are widely used because of their availability and low cost. Noncommercial biomass is available almost everywhere, and many people think of it as being "free" if they collect it themselves, or very cheap if they purchase it. In comparison, the overhead cost of acquiring kerosene or LPG stoves and bottles can discourage people from using those fuels, and even if some families can afford other fuels, the required infrastructure may not be available.[c]

Although the direct economic costs of using biomass may be small, the indirect costs in terms of agriculture, environment, and public health can be high. For example, time spent gathering fuel could be used instead for agricultural production; and biomass used for fuel, such as agricultural residues and dung, could be used instead for fertilizer. It has been estimated that, in India, dung used for fuel in 1998 would have been worth $800 million as fertilizer for use in agriculture.[d]

The use of biomass as fuel, when managed sustainably (that is, when biomass is planted or naturally replaced at the same rate it is harvested), does not harm either the local or global environment. Unsustainable harvesting of wood can, however, cause local deforestation and, potentially, loss of biodiversity. Globally, the extraction and burning of biomass releases carbon dioxide into the atmosphere; however, there is no net release of carbon dioxide if biomass is planted and harvested at the same rate, because growing plants remove and sequester carbon dioxide from the atmosphere.

Harvesting of fuelwood in developing countries is not considered to be a significant cause of large-scale deforestation. In general, people do not fell trees in their search for firewood, preferring instead to collect woody shrubs, fallen branches, or debris from cleared agricultural fields. In addition, fuelwood is rarely harvested from natural forests. Near cities with large numbers of urban poor and a lack of electrification, fuelwood or charcoal (made locally from wood) continues to be used widely as a household energy source, and the high demand for woody biomass concentrated geographically can lead to over-exploitation of forest resources near the city.

More significant adverse consequences from the use of biomass as a household energy source are associated with the indoor air pollution caused by fumes and emissions from stoves. For example, one recent study has shown that 24-hour average indoor concentrations of small particle emissions in Indian households that use solid fuels for cooking and heating can be as high as 2,000 micrograms per cubic meter[e] and can exceed World Health Organization guidelines by a factor of 10, 20, or more. For comparison, average annual outdoor concentrations of small particles (less than 10 microns in diameter) are generally less than 30 micrograms per cubic meter in U.S. cities and between 90 and 600 micrograms per cubic meter at outdoor urban monitoring stations in India.[f]

(continued on page 141)

[a]International Energy Agency, *Biomass Energy: Data, Analysis, and Trends* (Paris, France, 1998).
[b]International Energy Agency, *World Energy Outlook 2002* (Paris, France, 2002).
[c]International Energy Agency, *World Energy Outlook 2002* (Paris, France, 2002).
[d]Tata Energy Research Institute (India), Energy Research Institute (China), Wageningen Agricultural University (Netherlands), and International Institute for Applied Systems Analysis (Austria), *Potential for Use of Renewable Sources of Energy in Asia and Their Cost Effectiveness in Air Pollution Abatement, Final Report on Work Package 1* (December 1999), web site www.dow.wau.nl/msa/renewables/Downloads/workpackage1/Final_report_workpackage_1.pdf.
[e]K.R. Smith, "National Burden of Disease in India from Indoor Air Pollution," *PNAS*, Vol. 97, No. 24 (November 21, 2000), p 13285.
[f]The World Bank Group, "The Inside Story: Indoor Air Pollution Implicated in Alarming Health Problems," *Indoor Air Pollution Newsletter: Energy and Health for the Poor*, No. 1 (September 2000), web site http://wbln0018.worldbank.org/sar/sa.nsf/2991b676f98842f0852567d7005d2cba/a169d6e66c9c0c7585256990006a2631?OpenDocument.

Noncommercial Biomass Energy Use in Developing Countries (Continued)

Exposure to indoor air pollution is especially high for women and children in developing countries. Women usually have primary responsibility for cooking, and small children (under the age of five) tend to remain indoors with their mothers. One of the major health risks associated with small particle air pollution in developing countries is acute respiratory infections associated with a wide range of viruses and bacteria. In India, acute respiratory infections account for nearly three-quarters of the deaths from causes associated with indoor air pollution.[g] Chronic obstructive pulmonary disease and lung cancer have also been associated with exposure to particulate matter from indoor air pollution, as have increases in risk for cataracts (leading to blindness), tuberculosis, asthma, and adverse pregnancy outcomes (including low birth weight, prematurity, and early infant death).

Indoor air pollution affects approximately 2.4 billion people worldwide and many countries have programs to address the issue. National policy initiatives include temporary or permanent subsidies for cleaner burning, better ventilated stoves; improved delivery of energy services to the poor, particularly in rural areas; microfinancing schemes to help the poor with initial investments in improved stoves; and investments in research and development for new technologies, financing mechanisms, and exposure and health assessments.[h]

[g] K.R. Smith, "National Burden of Disease in India from Indoor Air Pollution," *PNAS*, Vol. 97, No. 24 (November 21, 2000), p 13291.
[h] The World Bank Group, "Regional Workshop on Household Energy, Indoor Air Pollution and Health," *Indoor Air Pollution Newsletter: Energy and Health for the Poor*, No. 8 (August 2002), web site http://lnweb18.worldbank.org/sar/sa.nsf/General/54F998E632F70B3685256DB70073A19A?OpenDocument.

would bring the total to 61.6 percent and enable the Kyoto Protocol to enter into force—regardless of the American and Australian decisions not to participate. Although Russia's President Vladimir Putin has announced Russia's intention to ratify the treaty, recent statements by his economic advisors suggest otherwise. Further clarification of Russia's position is unlikely until well after its March 2004 presidential and legislative elections.

A few Kyoto Protocol issues remain unresolved, some of which can be finalized only when the Protocol has entered into force. They include targets and procedures for subsequent commitment periods and the issue of technology transfer between countries to enable more rapid emissions reductions. Other unresolved issues include the accounting rules for carbon sink projects, and whether the consequences for noncompliance in meeting national emission reduction targets should be legally binding.

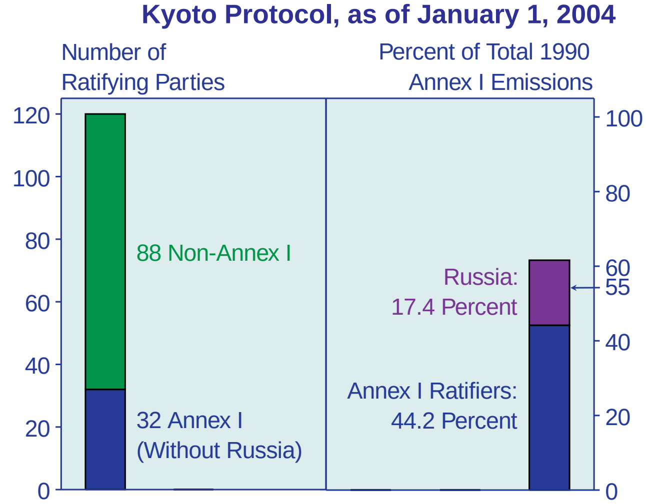
Although the Kyoto Protocol is not yet in force, many governments have been trying to reduce greenhouse gas emissions through a variety of domestic and international policies. Policies target all areas of energy use in industry, energy production, transportation, and buildings (Table 18).

The *IEO2004* reference case projections indicate that energy-related carbon dioxide emissions from the entire Annex I group of countries will exceed the group's 1990 emissions level in 2010. In addition, although energy-related carbon dioxide emissions from the group of transitional Annex I countries decreased significantly between 1990 and 2000 as a result of economic and political crises in the EE/FSU, they showed an increase from 2000 to 2001 and are projected to continue increasing over the forecast period. The combined Kyoto Protocol reduction target for the transitional Annex I countries is 10 percent below their projected 2010 baseline emissions.

Greenhouse Gas Emissions Trading

At COP-7 in Marrakech, it was established that international emissions trading under the Kyoto Protocol could start in 2008. In advance of any international emissions

Figure 74. Progress Toward Ratification of the Kyoto Protocol, as of January 1, 2004



Sources: United Nations Framework Convention on Climate Change, web site www.unfccc.int; and S. Ruth and A. Retyum, "CERA Decision Brief: Russia: Holding the Kyoto Trump Card" (Cambridge, MA: Cambridge Energy Research Associates, September 2002).

trading under the Protocol, however, some Annex I parties have established or are in the process of establishing their own internal greenhouse gas emissions trading programs. The economic rationale behind emissions trading is to reduce the costs associated with achieving a set reduction in greenhouse gases. Trading works by encouraging the covered participants with low-cost options to reduce their emission levels to below their allotted share and to make the surplus reductions available to participants whose reduction options are more costly.

One framework for emissions trading is "cap and trade," whereby a regulatory authority would establish a permanent cap on aggregate emissions for a group of emitters. The cap could, for example, be set at a fraction of the historic emissions from the group of participants. The cap would be divided into a set number of allowances, each of which would give the holder the right to emit a specified quantity of the regulated pollutant in a given compliance period. In the case of greenhouse gas emissions, each allowance could grant the holder the right to emit 1 metric ton of carbon dioxide. Once distributed among the participants, the allowances could be bought, sold, or (possibly) banked for future use. At the end of each compliance period, each participant would be required to hold allowances equal to its actual emissions or else face a penalty. Although it has not been used to achieve a mandatory large-scale reduction of greenhouse gas emissions, the cap and trade system has been used successfully in the United States since the 1990s to achieve reductions in stationary-source emissions of sulfur dioxide. In the late 1980s, New Zealand introduced an individual transferable quota system for managing fisheries, setting a total allowable catch and allocating tradable shares to individual fishermen. The system has since been emulated in more than 75 countries [*4*].

Emissions trading could also be based on concepts other than cap and trade. For example, a "credit-based" emissions trading system would include both capped and

Table 17. Quantified Emissions Reduction Targets Under the Kyoto Protocol by Country

Country	Reduction Target (Percent)	Country	Reduction Target (Percent)
Australia	+8.0	Liechtenstein	-8.0
Austria (R)	-13.0	Lithuania (R)	-8.0
Belgium (R)	-7.5	Luxembourg (R)	-28.0
Bulgaria (R)	-8.0	Monaco	-8.0
Canada (R)	-6.0	Netherlands (R)	-6.0
Croatia	-5.0	New Zealand (R)	0.0
Czech Republic (R)	-8.0	Norway (R)	+1.0
Denmark (R)	-21.0	Poland (R)	-6.0
Estonia (R)	-8.0	Portugal (R)	+27.0
European Community (R)[a]	-8.0	Romania (R)	-8.0
Finland (R)	0.0	Russia	0.0
France (R)	0.0	Slovakia (R)	-8.0
Germany (R)	-21.0	Slovenia (R)	-8.0
Greece (R)	+25.0	Spain (R)	+15.0
Hungary (R)	-6.0	Sweden (R)	+4.0
Iceland (R)	+10.0	Switzerland (R)	-8.0
Ireland (R)	+13.0	Ukraine	0.0
Italy (R)	-6.5	United Kingdom (R)	-12.5
Japan (R)	-6.0	United States	-7.0
Latvia (R)	-8.0		

(R) = Country has ratified, accepted, approved, or acceded to the Kyoto Protocol.

[a]European Union member countries renegotiated their individual targets under the EU Shared Burden Agreement, which was agreed to in 1998 and reaffirmed in the ratification of the Kyoto Protocol in 2002.

Sources: For countries in the European Union: European Environmental Agency, *Greenhouse Gas Emission Trends and Projections in Europe: 2003: Tracking Progress by the EU and Acceding and Candidate Countries Towards Achieving Their Kyoto Protocol Targets*, Environmental Issue Report No. 36 (Copenhagen, Denmark, 2003), web site http://reports.eea.eu.int/environmental_issue_report_2003_36/en/TPreport_final_draft_ 5_dec.pdf. For all other countries: "Kyoto Protocol to the United Nations Framework Convention on Climate Change," web site http://unfccc.int/ resource/docs/convkp/kpeng.pdf.

non-capped industries and entities that would trade voluntarily created, permanent emission reduction credits legally recognized by a regulator. This system would allow entities with emissions increases to obtain offsetting reductions from other entities. Other trading variants include "baseline" emissions trading systems, which would allow entities to reduce emissions below a "business-as-usual" level and then trade the emission reductions. "Rate-based" emissions trading would focus on emissions per unit of output rather than absolute emissions, allowing entities that improved their efficiency beyond target levels to trade the excess improvement with other entities. Some trading systems combine two or more methods to regulate different sectors more efficiently.

In 2003, the European Parliament and the Council of Ministers agreed on a directive establishing a scheme for trading of greenhouse gas emission allowances [*5*]. The cap and trade system will include all member states from 2005 forward but give member states the right to exempt individual sectors, activities, or installations until 2008 if comparable emission reductions are already being undertaken. In the first compliance period at least 95 percent of the allowances will be free; by the second compliance period, at least 90 percent of the allowances will be free. The first trial phase of the trading scheme will run from 2005 through 2007, regulating carbon dioxide emissions from all heat and electricity generators with more than 20 megawatts of rated thermal input capacity and from all refineries, coke ovens, iron and steel production processes, pulp and paper plants, and mineral industry installations. The proposal requires operators of such installations to hold permits as a condition for emitting greenhouse gases. Regulations can be changed and renegotiated for the second phase of the scheme, which will be concurrent with the first compliance period under the Kyoto Protocol (2008-2012). Each subsequent EU emissions trading phase will last for 5 years.

The EU member states will determine the quantity of allowances to be issued in each phase. Noncompliance sanctions will be applied to any installation that does not have enough allowances to cover actual emissions each year. The allowances, which will be tradable across the entire EU, can be banked from year to year within each phase and across phases if individual member states decide to do so.

The EU proposal is designed to be compatible with international emissions trading under the Kyoto framework; however, any other agreements recognizing third countries' emission trading schemes must be subject to

Table 18. Sample Policies and Measures To Reduce Greenhouse Gas Emissions in Annex I Countries

Regulatory Instruments	Policy Processes	Fiscal Instruments	Voluntary Agreements	Tradable Permits
United States (New Hampshire): Carbon dioxide emission reductions from existing fossil-fuel-burning steam-electric power plants to 3 percent below 1999 levels by 2006 (2002) Norway: Energy labels for household appliances Japan: Electricity suppliers to provide a specified percentage of energy from solar, wind, geothermal, biomass, and small- to medium-sized hydropower plants. Overall target is a 400-percent increase in renewable generation by 2010 Australia: Fuel consumption labels on cars (2001) United Kingdom: Renewables obligation on electricity supply	Ireland: Sustainable energy program created to promote environmentally and economically sustainable production; energy efficiency and renewable energy; and reduction of greenhouse gas emissions France: Mass media climate change campaign Denmark: Instituted labeling on cars to inform consumers of vehicle efficiency and carbon dioxide emissions Belgium: Planning to increase rail transport by 15 percent	Netherlands: "Eco-tax" exemptions for green electricity use Luxembourg: Grants for purchase of efficient vehicles (2001) Denmark: Higher energy taxes on natural gas, gasoline, diesel, diesel light, fuel oil, coal, and electricity Denmark: Reduced car registration fees for fuel-efficient vehicles	Canada: Agreement with the Aluminum Association of Canada's member companies to reduce greenhouse gas emissions from their Quebec-based facilities by approximately 200,000 metric tons by the end of 2007 France: Government-industry agreement to reduce greenhouse gas emissions; companies not achieving reduction goals in 2004 and 2007 will pay fines Netherlands: Agreement with six coal-fired power plants to reduce carbon dioxide emissions by 6 million metric tons between 2008 and 2012 Japan: Suggestion that federal, regional, and local governments deploy 10 million low-pollution vehicles and 50,000 fuel cell cars by 2010	United Kingdom: National economy-wide greenhouse gas emissions trading scheme with voluntary participants Austria: Green certificate trading (2000) Denmark: Carbon dioxide emissions trading system for electricity producers Belgium: Green certificates must be bought by grid operator for offshore wind energy, onshore wind energy, hydropower, solar energy, and biomass energy

Notes: Regulatory instruments include mandates, standards, and regulations. Policy processes include planning, information, and consultation. Fiscal instruments include taxes, tax exemptions/credits, incentives, and subsidies. Voluntary agreements are with industry/consumer groups.
Source: Energy information Administration, Office of Integrated Analysis and Forecasting.

COP-9 Climate Change Negotiations in Milan, Italy

The Ninth Session of the Conference of the Parties to the UNFCCC (COP-9) was held in Milan, Italy, from December 1 to December 12, 2003. Discussion continued on the Kyoto Protocol and the implementation of the UNFCCC. With the United States publicly stating that it will not ratify the Protocol, entry into force is dependent on ratification by Russia; however, signals from the Russian government were mixed. Early in the conference, a spokesman for the Russian treasury department stated that Russia would not ratify the Protocol. Shortly thereafter, another cabinet member expressed Russia's full intent to ratify the Protocol.

The EU has stated that it will undertake policies and measures, including a cap and trade regime, to reach the Kyoto targets regardless of Russia's final decision on ratification. It is clear, however, that the costs of reaching the targets will increase in the absence of tradable permits from Russia. By virtue of the economic collapse of the Soviet Union, Russia is below its target under the Protocol. By the end of COP-9, the Russian delegation had made explicit its calls for EU concessions on non-Protocol matters, such as trade and EU membership, as a condition for Russia's ratification.

The most important decisions reached at COP-9 pertained to rules for carbon sink projects during the first commitment period. Two years earlier, at COP-7, the parties agreed that afforestation and reforestation projects would be allowed under CDM but did not set detailed rules for such projects. The problem with establishing rules for afforestation and reforestation projects is that forests are not permanent. Before COP-9, the parties had not decided who should be liable if a sink began releasing its sequestered carbon dioxide into the atmosphere—the project developer, the host country, or the holder of emissions reductions credits for the project. At COP-9 they decided to create temporary emissions reductions credits that would be valid for only one commitment period, as well as long-term credits that could be renewed for 20-year periods. This accounting system would assign responsibility for maintaining sinks to the holder of the reduction credits, ensuring that holders could take credit only for current emission reductions. The EU delegation also sought to open discussion of the second commitment period (2012-2016), but others were not prepared to do so. The Kyoto Protocol calls for negotiations for the second commitment period to begin no later than 2005.

In addition to the official negotiations at COP-9, there were more than 100 side events hosted by various governmental and nongovernmental organizations. Participants discussed a wide array of subjects, among which the CDM was prominent. Topics in the CDM discussions included rules to help reduce poverty in the developing world and to increase private-sector involvement in CDM projects.[a] Other subjects of discussion included countries' domestic climate change policies, technical issues related to greenhouse gas inventories, directions and proposals for the climate regime after 2012, and examples of corporate responses to climate change. Although the side events were not part of the official negotiations, they were an important part of COP-9, allowing participants to share mitigation strategies, suggest ideas for future negotiations (for instance, rulemaking for the CDM), and consider the future of the UNFCCC beyond the Kyoto Protocol.

[a]United Nations Framework Convention on Climate Change, Ninth Session of the Conference of the Parties and the Nineteenth Session of the Subsidiary Bodies, 1-12 December 2003, Milan, Italy, "Side Events and Exhibits," web site: http://unfccc.int/cop9/se/se_schedule.html.

ratification of the Protocol, effectively excluding participation by non-Kyoto countries (such as Australia and the United States). Moreover, the proposal is open to the use of the Kyoto Protocol's joint implementation and clean development mechanisms, perhaps as early as the first phase, although the use of carbon "sinks" or nuclear projects may be excluded. In conjunction with the introduction of the EU trading program, several EU member countries, including Denmark, France, Germany, Ireland, the Netherlands, and the United Kingdom, are considering development of their own national trading programs. Outside the EU, Japan and Slovakia have also announced that they intend to establish trading systems.

Currently, Denmark is the only country that has instituted a mandatory cap and trade system to reduce carbon dioxide emissions from electricity producers [*6*]. The program began in 2001 with a cap of 22 million metric tons of carbon dioxide, which is to be lowered by 1 million metric tons each year during the 3-year life of the program. The cap and trade system applies only to companies that emit at least 100,000 metric tons of carbon dioxide. Eight companies, which emit more than 90 percent of the carbon dioxide from electricity generation in Denmark, are required to participate in the trading scheme. Allowances under the system were allocated on the basis of each firm's fuel consumption and actual emissions during the 1994-1998 period, excluding emissions from purchased power.

In 2001 and 2002, the average price of traded allowances under the Danish system was lower than the noncompliance penalty tax, giving companies an incentive to trade for allowances rather than simply paying the penalty [*7*]. As of late 2002, however, the number of allowances available for trading was too small to permit active trading. As a result, companies have relied on bilateral negotiations to establish contracts for the sale and purchase of allowances [*8*]. If the program is extended, its allowances are likely to be compatible with the proposed EU trading scheme.

The compatibility of the EU proposal with the United Kingdom's voluntary emissions trading program, which entered into effect in April 2002, is more questionable. The programs differ in several respects, including rules for participation, generation of allowances, and sectoral coverage. Under the British program, any company can opt to enter the trading scheme by negotiating energy efficiency targets or absolute emission reduction targets in return for incentive payments offered by the government. Companies can report on direct emissions and indirect emissions from imported energy and will earn tradable allowances for carbon dioxide reductions computed against their targets.

Also in contrast to the EU proposal, the U.K. scheme is based on voluntary targets, includes all six Protocol gases, and excludes combined heat and power generators, except for emissions from electricity that is generated and used on-site [*9*]. The scheme completed its first year of trading in December 2002, and reports show that 31 of the 32 remaining participants achieved their targets. Over 5 years, the scheme is expected to reduce carbon dioxide emissions by nearly 4 million metric tons [*10*].

In anticipation of entry into force of the Kyoto Protocol, private firms and national governments have started investing in greenhouse gas reduction projects and trading in greenhouse gas offset credits, contributing to the emergence of a nascent market in the credits. Since 1996, carbon transactions amounting to 375 million metric tons of carbon dioxide reductions have been recorded [*11*]. Major market drivers include the U.K. emissions trading scheme, the World Bank's Prototype Carbon Fund, the upcoming EU emissions trading program, and the Dutch government's programs to procure joint implementation and clean development mechanism credits. Emissions reductions purchased by the Prototype Carbon Fund average about $5 per metric ton carbon dioxide, and credits purchased by the Dutch government average just less than $7 per metric ton [*12*]. Prices in the U.K. emissions trading system have varied from $22 per metric ton in September 2002 to about $5 per metric ton in early 2003 [*13*].[19]

In general, the focus in the market is shifting from North America toward Europe, largely because of the U.S. decision not to ratify the Kyoto Protocol, the startup of the U.K. emissions trading system, and the upcoming European-wide trading scheme. Emissions trading activity in the United States could increase, however, following the December 12, 2003, opening of trading on the Chicago Climate Exchange (CCX). The CCX is a voluntary cap and trade program in which participating members will be able to buy and sell greenhouse gas credits to assist in achieving their voluntary emission reduction commitments.

Abatement of Conventional Pollutants from Energy Use

Many countries currently have policies or regulations in place that limit energy-related emissions other than carbon dioxide. Energy-related air pollutants that have received particular attention include nitrogen oxides, sulfur dioxide, lead, particulate matter, and volatile organic compounds, because of their contribution to ozone and smog formation, acid rain, and various human health problems (Table 19). Moreover, in some countries regulation of mercury emissions associated with energy combustion has recently become an issue. Countries also regulate the management of spent fuel from nuclear power generation facilities, but none of the countries with active nuclear power programs has yet established a permanent disposal system for highly radioactive waste. How countries limit energy-related emissions by legislation and/or regulation can have significant impacts on energy technology choices and energy use.

Regulated air pollutants can be attributed to a mix of mobile and stationary energy uses. Nitrogen oxide emissions come from high-temperature combustion processes, such as those that occur in motor vehicles and power plants; road transportation is generally the single largest source. Sulfur dioxide is formed during the burning of high-sulfur fuels for electricity generation, metal smelting, refining, and other industrial processes; coal-fired power plants account for the preponderance of sulfur dioxide emissions. Volatile organic compounds are emitted from a variety of sources, including motor vehicles, chemical plants, refineries, factories, consumer products, and other industrial sources. Particulate matter can be emitted directly or can be formed indirectly in the atmosphere: "primary" particles, such as dust from roads or elemental carbon (soot) from wood combustion, are emitted directly into the atmosphere; "secondary" particles are formed in the atmosphere

[19]The high prices in September 2002 probably resulted from two external factors. First, some companies had to meet an emissions reduction compliance period as of October 2003. At the same time, many companies that had bought allowances in the auction in April 2002 had not yet received them. Thus, the high price was related more to the initial market setup and external factors than to the equilibrium price of allowances in the United Kingdom.

from primary gaseous emissions. Emissions of lead usually originate from motor vehicles that burn leaded gasoline. Emissions of mercury can be attributed to coal-fired boilers, municipal waste combustors, medical waste incinerators, and manufacturing processes that use mercury as an ingredient or raw material. Coal-fired boilers contribute the largest share of mercury emissions [*14*].

With the tightening of emissions limits on combustion plants during the 1990s, sulfur dioxide emissions declined in many industrialized countries. In Europe, the shift from coal to natural gas for electricity production (most notably, in the United Kingdom and Germany) also contributed to a reduction in the region's sulfur dioxide emissions. Many industrialized countries (including Japan, the United States, and the EU) have scheduled further restrictions on sulfur dioxide emissions from stationary sources to take effect over the next 10 years.

With the decrease in atmospheric concentrations of sulfur dioxide in industrialized countries, attention has shifted to ozone, nitrogen oxides, and particulates. Despite the imposition of emissions regulations, nitrogen oxide emissions rose during the 1990s in many industrialized countries as a result of continued increases in consumption of transportation fuels. In Europe, however, the decrease in coal-fired electricity generation and the introduction of catalytic converters on vehicles led to a gradual drop in nitrogen oxide emissions [*15*]. In contrast to the generally rising trend in nitrogen oxide emissions, emissions of volatile organic compounds have declined [*16*]. To continue combating ground-level ozone formation, several countries plan to tighten emissions standards for new vehicles over the coming years (Table 20). Limits on the sulfur content of gasoline and diesel fuel also are being imposed in order to ensure the effectiveness of emission control technologies used to meet new vehicle standards (Table 21).

The harmful effects of lead, especially for children, have been well established over the past three decades. As recently as 1990 leaded gasoline represented 57 percent of the global gasoline market, but as of January 1, 2004, although it was being sold in 73 countries, it accounted for less than 10 percent of the global market [*17*]. Most of the countries where leaded gasoline is still used are in Africa and the FSU, and a few are in the Middle East and Latin America (Figure 75). In countries that have not yet switched to unleaded fuel, leaded gasoline is a major source of lead pollution in urban areas, often accounting for more than 90 percent of atmospheric lead emissions [*18*] (see box on page 149).

Table 19. Possible Health and Environmental Effects of Major Air Pollutants

Air Pollutant	Nature of Pollutant	Possible Health and Environmental Effects
Nitrogen Oxides (NO_x)	Includes nitric oxide, nitrogen dioxide, and other oxides. Precursor of ozone and particulate matter.	Respiratory illnesses, haze, acid rain, and deterioration of water and soil quality.
Sulfur Dioxide (SO_2)	Family of sulfur oxides gases. Precursor of particulate matter.	Asthma, heart disease, respiratory problems, and acid rain.
Volatile Organic Compounds (VOC)	Precursor of ozone and particulate matter.	Respiratory and heart problems, acid rain, and haze.
Particulate Matter (PM)	Mixture of solid particles and liquid droplets formed by sulfur dioxide, nitrogen oxides, ammonia, volatile organic compounds, and direct particle emissions. Smaller particles (less than 2.5 microns) are more harmful to the lungs.	Respiratory and heart problems, acid rain, and haze.
Mercury (Hg)	Metallic element that, when it enters a body of water, is transformed by biological processes into a toxic form of mercury (methylmercury).	Mercury in ambient air is deposited on land surfaces or into rivers, lakes, and oceans, where it can concentrate in fish and other organisms. Exposure to methylmercury from eating contaminated fish and seafood may cause neurological and developmental damage.
Lead (Pb)	Metallic element that can be introduced to people through air, water, or ingestion. Within the body, lead is stored in bones.	Lead interferes with the development of the nervous system and is most harmful to young children and pregnant women. High levels of lead in the bloodstream can cause irreversible learning disabilities, behavioral problems, and mental retardation. Lead interferes with the metabolism of calcium and vitamin D, can damage the reproductive system and the kidneys, and can cause high blood pressure and anemia.

Sources: U.S. Environmental Protection Agency, *Latest Findings on National Air Quality: 2001 Status and Trends*, EPA 454/K-02-001 (Washington, DC, September 2003); National Research Council, *Toxicological Effects of Methylmercury* (Washington, DC, 2000); C.L. French, W.H. Maxwell, W.D. Peters, G.E. Rice, O.R. Bullock, A.B. Vasu, R. Hetes, A. Colli, C. Nelson, and B.F. Lyons, *Study of Hazardous Air Pollutant Emissions from Electric Utility Steam Generating Units: Final Report to Congress, Volumes 1-2*, EPA-453/R-98-004a and b (Research Triangle Park, NC. February 1998).

Over the past several decades, many nations have begun to evaluate the potential adverse effects of mercury on human health and the environment. Although mercury is an element that occurs naturally throughout the world, exposure to mercury is dangerous for people and animals because their bodies neither break down nor readily excrete the metal. Mercury is a bioconcentrator: over time, mercury in the blood of animals at low trophic levels will be passed on to predators at higher trophic levels.[20] Swordfish, salmon, fish-eating birds, and seals are among the animals most affected by the bioconcentration of mercury. Although mercury exists both onshore and in the marine environment, predators in the marine ecosystem often have higher concentrations of mercury because there are more trophic levels in the aquatic ecosystem, and thus more opportunities for bioconcentration [*19*].

Mercury emissions from energy use have recently become an area of particular concern in the industrialized countries. Major anthropogenic sources of mercury emissions include stationary energy combustion, nonferrous metal production, pig iron and steel production, cement production, oil and gas processing, and waste disposal. Of these, only electricity generation, municipal solid waste combustion, and oil and gas processing are related to energy use. In the past, regulation of energy-related mercury has focused on municipal solid waste combustion; however, coal-fired boilers account for the largest remaining share of energy-related mercury

Table 20. Current and Future Nitrogen Oxide Emission Standards for New Vehicles in Selected Countries

Vehicle Type	Vehicle Class	United States		European Union		Australia	
		Limit	Date	Limit	Date	Limit	Date
Gasoline . .	Light Duty	0.60-1.53 g/mile	Current standard	0.15-0.21 g/km	Current standard	0.63-1.40 g/km	Current standard
		0.07 g/mile	Phase-in 2004-2007	0.08 g/km[b]	Starting 2005	0.22 g/km	Starting 2003
				0.1-0.11 g/km[c]	Starting 2006	0.15-0.21 g/km	Starting 2005
	Heavy Duty	4.0 g/bhp-hr	Current standard				
		1.0 g/bhp-hr[a]	Starting 2004				
		0.2 g/bhp-hr	Phase-in 2008-2009				
Diesel	Light Duty	0.97-1.53 g/mile	Current standard	0.50-0.78 g/km	Current standard	0.78-1.20 g/km	Current standard
		0.07 g/mile	Starting 2004	0.25-0.39 g/km	Starting 2005	0.50-0.78 g/km	Starting 2003
	Heavy Duty	4.0 g/bhp-hr	Current standard	5.0 g/kWh	Current standard	8.0 g/kWh	Current standard
		1.0 g/bhp-hr[a]	Starting 2004	3.5 g/kWh	Starting 2005	5.0 g/kWh	Starting 2002
		0.2 g/bhp-hr	Phase-in 2007-2010	2.0 g/kWh	Starting 2008	3.5 g/kWh	Starting 2006

[a]Combined nitrogen oxide and hydrocarbon emissions limit.
[b]For passenger cars and class I light commercial vehicles.
[c]For other light commercial vehicles.
Note: The mix of vehicle types varies by region.
Sources: **United States:** U.S. Environmental Protection Agency, Office of Mobile Sources, *Emission Facts*, EPA-420-F-99-017 (Washington, DC, May 1999). **European Union:** European Parliament, Directive 98/69/EC, Official Journal L 350 (December 28, 1998), and Directive 99/96/EC, Official Journal L 44 (February 16, 2000). **Australia:** Department of Transport and Regional Services, "Vehicle Emission Australian Design Rules (ADRs)" (August 7, 2001).

Table 21. Future Sulfur Content Limits on Motor Fuels in Selected Countries

Fuel	United States		European Union		Australia	
	Limit	Date	Limit	Date	Limit	Date
Gasoline	30 ppm	Phase-in 2004-2006	50 ppm	As of 1/1/2005	500 ppm[a]	Current Standard
					150 ppm[b]	Current Standard
					150 ppm[c]	As of 1/1/2005
Diesel	15 ppm	As of 6/1/2006	50 ppm	As of 1/1/2005	500 ppm	As of 12/31/2002
			10 ppm	As of 1/1/2009	50 ppm	As of 1/1/2006

[a]For unleaded gasoline and lead replacement gasoline.
[b]For premium unleaded gasoline.
[c]For all grades.
Sources: **United States:** U.S. Environmental Protection Agency, "Control of Air Pollution from New Motor Vehicles: Tier 2 Motor Vehicle Emission Standards and Gasoline Control Requirements," *Federal Register* (February 10, 2000). **European Union:** European Parliament, Directive 98/70/EC, Official Journal L 350 (December 28, 1998); and "E.U. Slashes Sulphur Content in Road Fuels from 2005," Reuters News Service Planet Ark (February 3, 2003), web site www.planetark.com/dailynewsstory.cfm?newsid=19675&newsdate=03-Feb-2003. **Australia:** Attorney General's Department, Office of Legislative Drafting, "Fuel Standards Quality Act of 2000: Fuel Standards (Diesel and Petrol)" (October 8, 2001).

[20]Trophic refers to levels in a food chain, from photosynthesizing plants at the bottom, to herbivores, to carnivores at the top of the chain.

emissions, and countries that rely heavily on coal-fired power generation are beginning to consider limits on mercury emissions from power plants [*20*] (see box on page 150).

Regional Status of Environmental Policies

Many countries around the world have enacted policies aimed at protecting the environment. In this section, environmental policies in a number of different countries are reviewed. The reviews are not intended to constitute an exhaustive list of environmental policies or countries but rather a sample of the programs that have been instituted around the world. This year, for the first time, discussions of environmental policies in Chile and Hungary are included in this section.

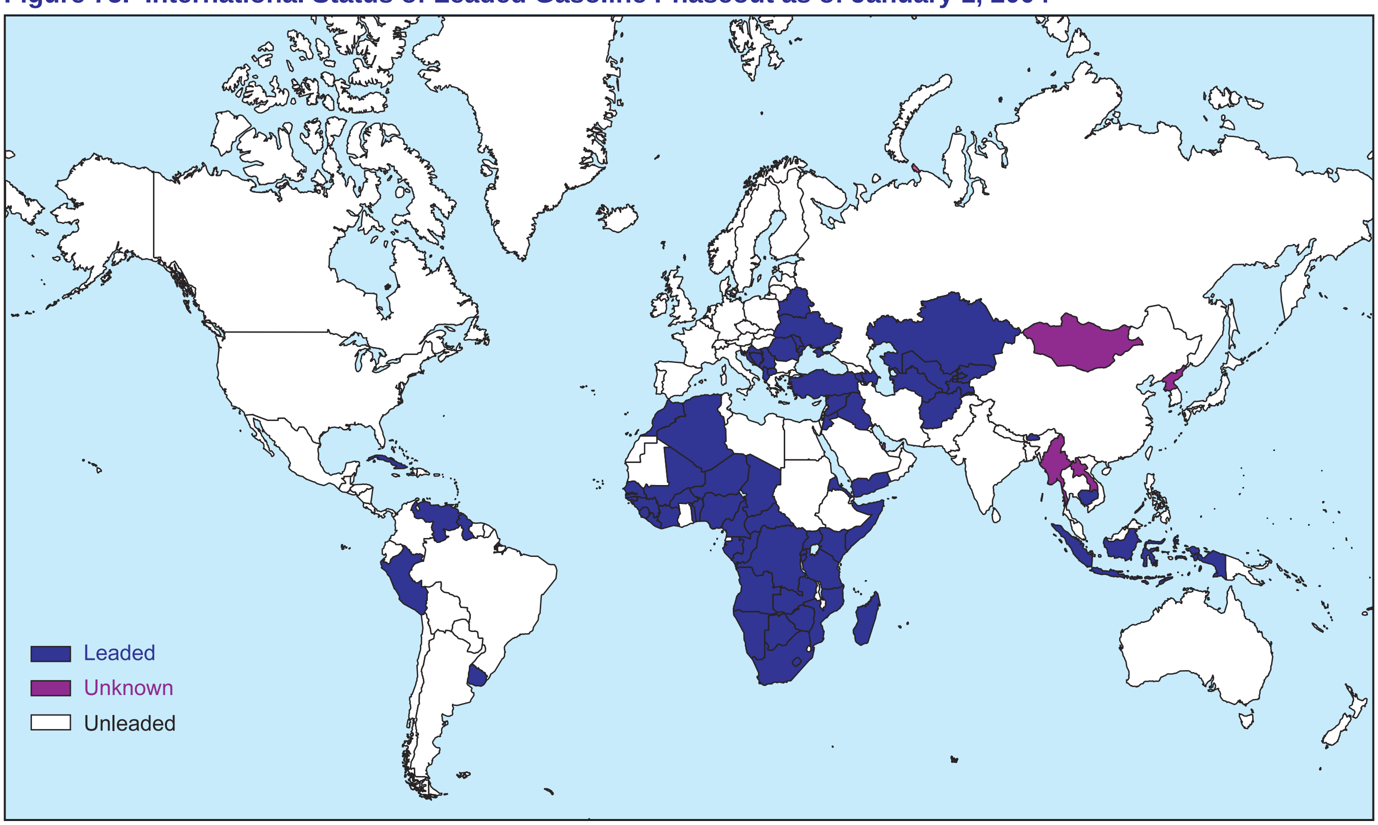
United States

The Clean Air Act of 1970 (CAA) is the comprehensive Federal law that regulates air emissions from stationary and mobile sources in the United States. It authorizes the U.S. Environmental Protection Agency (EPA) to establish National Ambient Air Quality Standards (NAAQS) to protect public health and the environment. The goal of the CAA was to set and achieve NAAQS in every State by 1975. The setting of maximum pollutant standards was coupled with directions for the development of State implementation plans (SIPs) for the regulation of emissions from local industrial sources. The CAA was amended in 1977 primarily to set new goals (dates) for the attainment of NAAQS, because many areas had failed to meet the deadlines for reducing airborne concentrations of the six "criteria pollutants" (carbon monoxide, lead, sulfur dioxide, nitrogen dioxide, ground-level ozone, and particulate matter).

The Clean Air Act Amendments of 1990 (CAAA90) addressed continuing problems associated with air emissions, including acid rain, ground level ozone, and visibility. Title IV of CAAA90, the Acid Rain Program, regulates both sulfur dioxide and nitrogen oxides. The program sets a goal of reducing annual sulfur dioxide emissions by 10 million tons below 1980 levels and annual nitrogen oxide emissions by 2 million tons below 1980 levels. In the United States in 2000, about 70 percent of annual sulfur dioxide emissions and 23 percent of nitrogen oxide emissions are produced from the burning of fossil fuels to generate electricity.

The Acid Rain Program specifies a two-phase reduction in emissions from fossil-fired electric power plants greater than 25 megawatts capacity and from all new power plants. Phase I was completed in 1999. Phase II of the program, which began in January 2000, lowered the total allowable level of sulfur dioxide emissions from all electricity generators, capping annual U.S.

Figure 75. International Status of Leaded Gasoline Phaseout as of January 1, 2004



Source: International Fuel Quality Center.

Leaded Gasoline: The Global Phaseout

Since the early 1920s, lead has been blended with gasoline to boost octane levels. In the 1970s and 1980s, however, it was established that lead is a toxin that particularly affects the neurological development of children: even low-level exposure to lead can cause reading and learning disabilities, changes in behavior, reduced attention span, and hearing loss; and greater exposure can lead to permanent mental retardation, convulsions, coma, and death.[a] As a result, many countries have banned the use of leaded gasoline—a transition that was facilitated in 1975 by the introduction of automobiles with catalytic converters that require lead-free fuel.[b]

The global phaseout of leaded gasoline has proceeded rapidly. Between 1970 and 1993, the total amount of lead added to gasoline worldwide dropped by 75 percent, from more than 375,000 tons to less than 100,000 tons.[c] Leaded gasoline made up more than 57 percent of the world gasoline market in 1990, but its share was less than 10 percent in 2003. As of January 1, 2004, 73 countries, mostly in Africa and Eastern Europe, were still using leaded gasoline (see Figure 75), and many of those countries, including Azerbaijan, Benin, Kazakhstan, Nigeria, and Uzbekistan, have plans to phase it out in the next few years.[d]

Some countries phased out lead in gasoline over relatively long periods; others did it in just 1 or 2 years. The United States moved relatively slowly, starting when the U.S. Environmental Protection Agency began to regulate the use of lead in gasoline in 1975. In 1973, the average lead content of gasoline in the United States was 2 to 3 grams per gallon, totaling about 200,000 tons of lead a year. In 1995, leaded fuel accounted for only 0.6 percent of total U.S. gasoline sales and less than 2,000 tons of lead per year. Lead was completely banned from use in on-road vehicle fuel in the United States as of January 1, 1996.[e]

In Pakistan, the phaseout was rapid by comparison. As recently as early 2001, only leaded gasoline was sold in Pakistan, but by mid-2002 its gasoline supply was virtually lead-free. The government of Pakistan partnered with the United Nations Development Programme and the World Bank in the Pakistan Clean Fuels Project to facilitate its phaseout of leaded gasoline. In July 2001, the government accelerated the phaseout by having three of the four refineries in the country begin selling only unleaded gasoline. Although environmental regulations in Pakistan still permit 0.35 grams per liter of lead in gasoline, all four of the country's refineries were producing unleaded gasoline by the end of 2003.[f]

[a]M. Lovei, *Phasing Out Lead From Gasoline: Worldwide Experience and Policy Implications*, World Bank Technical Paper No. 397: Pollution Management Series (1998).
[b]J. Lewis, "Lead Poisoning: An Historical Perspective," *EPA Journal* (May 1985), web site www.epa.gov/history/topics/perspect/lead.htm.
[c]United Nations Environmental Program, *Global Opportunities for Reducing the Use of Leaded Gasoline* (1998), web site www.chem.unep.ch/pops/pdf/lead/toc.htm.
[d]International Fuel Quality Center, *Current Status of Leaded Gasoline Phase Out Worldwide* (February 4, 2003) (updated by personal communication, October 30, 2003).
[e]U.S. Environmental Protection Agency, "EPA Takes Final Step in Phaseout of Leaded Gasoline" (Press Release, January 29, 1996), web site www.epa.gov/history/topics/lead/02.htm.
[f]International Fuel Quality Center, Asian Office, personal communication, November 5, 2003.

emissions at 8.95 million tons by 2010.[21] The sulfur dioxide regulations include a highly successful market-based regulatory program, which allows individual plant operators to reduce their emissions through any combination of strategies, including installation of scrubbers, switching to low-sulfur fuels, and trading and banking of emissions allowances. This cap and trade approach, which allows emitters to choose the most cost-effective means for limiting sulfur dioxide emissions, has led to a 24-percent decrease in sulfur dioxide emissions between 1992 and 2001 [***21***].

Specifications for reducing nitrogen oxide emissions under the Acid Rain Program also call for a two-phase approach. Phase I, beginning in 1995, aimed to reduce emissions from coal-fired electric power plants by more than 400,000 tons per year. Phase II, which began in 2000, aimed for a reduction of more than 2 million short tons per year. Unlike the sulfur dioxide reduction program, the nitrogen oxide program does not use an emissions cap and trade program. Rather, the EPA has set emission limits by boiler type. A coal-fired power plant can meet the requirements in three ways: (1) meet the standard annual emission limit for each boiler, (2) average the emissions rates of two or more boilers, or (3) apply for a less stringent alternative emission limit and use appropriate emission control technology [**22**].

The EPA has also taken two actions to address the effects of interstate transport of nitrogen oxide emissions on

[21]Because some power companies accumulated (banked) emissions allowances during Phase I of the program (1995 to 1999), the Phase II cap of 8.95 million tons per year will not be reached until the banked allowances have been exhausted.

Controlling Emissions of Mercury from Energy Use

In response to scientific research indicating potential adverse ecological and human health impacts caused by exposure to mercury, many nations are considering regulation and control of mercury emissions—including those attributed to energy use.

Recent estimates of global mercury emissions indicate that Europe and North America contribute less than 25 percent of global anthropogenic emissions (see table below). The majority of emissions originate from combustion of fossil fuels, particularly in Asian countries that rely heavily on coal for electricity generation, including China, India, and South and North Korea.[a] Other sources of mercury include processing of mineral resources at high temperatures, such as roasting and smelting of ores, kiln operations in the cement industry, incineration of waste materials, and production of certain chemicals.

Traditionally, regulation of energy-related mercury emissions has focused on municipal solid waste combustion.[b] Mercury is found in relatively higher concentrations in waste incineration exhaust gases than in the gases released from coal combustion and is thus simpler and less expensive to remove. As a result, most industrialized and many developing countries already have standards in place to control mercury levels in the exhaust gases from waste incineration facilities and in wastewater from the cleaning of their exhaust gases (see table on page 151).[c]

A number of countries, including Canada, the United States, and the European Union, are now considering standards to control mercury emissions from coal-fired electricity generators:[d]

- Under the umbrella of the Canadian Council of Ministers of the Environment, federal, provincial, and territorial governments in Canada have agreed to develop a nationwide emission standard for the coal-fired electricity generation sector by the end of 2005 and to reduce mercury emissions from coal-fired power plants by 2010.[e]
- The United States is debating various multi-pollutant legislative initiatives, with mercury as one of the targeted pollutants. In December 2002, the EPA found that it is appropriate and necessary to regulate hazardous air pollutants, including mercury from electric power plants.[f] The EPA proposed Utility Mercury Reductions in December 2003 and currently is seeking comment on two types of emissions reductions mechanisms, one based on maximum achievable control technologies (MACT) and another based on a cap and trade system. A final rule will be promulgated in December 2004.

(continued on page 151)

Emissions of Mercury from Anthropogenic Sources by World Region, 1995
(Metric Tons per Year)

Region	Source of Emissions: Stationary Combustion of Fossil Fuels	Nonferrous Metal Production	Pig Iron and Steel Production	Cement Production	Waste Disposal	Total
Asia	860	87	12	82	33	**1,074**
Europe	186	15	10	26	12	**248**
North America	105	25	5	13	66	**214**
Africa	197	8	1	5	—	**211**
Australia and Oceania	100	4	0	1	0	**106**
South America	27	25	1	6	—	**59**
Total	**1,475**	**166**	**29**	**132**	**111**	**1,913**

Source: See note a below.

[a]European Commission, *Ambient Air Pollution by Mercury (Hg): Position Paper* (Luxembourg: Office for Official Publications of the European Communities, 2001), web site http://europa.eu.int/comm/environment/air/background.htm.

[b]Municipal solid waste combustion is considered an energy source, because many incinerators produce steam for heating.

[c]United Nations Environment Programme, *Global Mercury Assessment. Appendix: Overview of Existing and Future National Actions, Including Legislation, Relevant to Mercury as of November 1, 2002* (Geneva, Switzerland, December 2002), web site www.chem.unep.ch/mercury/Report/Finalreport/final-appendix-1Nov02.pdf; and “Directive 2000/76/EC of the European Parliament and of the Council of 4 December 2000 on the Incineration of Waste,” *Official Journal of the European Communities*, L332/91 (December 28, 2000), web site http://europa.eu.int/comm/environment/wasteinc/newdir/2000-76_en.pdf.

[d]United Nations Environment Programme, *Global Mercury Assessment. Appendix: Overview of Existing and Future National Actions, Including Legislation, Relevant to Mercury as of November 1, 2002* (Geneva, Switzerland, December 2002), web site www.chem.unep.ch/mercury/Report/Finalreport/final-appendix-1Nov02.pdf.

[e]Canadian Council of Ministers of the Environment, “CWS for Mercury From Coal-Fired Electric Power Generation Sector,” web site www.ccme.ca/initiatives/ standards.html?category_id=53.

[f]U.S. Environmental Protection Agency, “Fact Sheet: EPA To Regulate Mercury and Other Air Toxics Emissions From Coal- and Oil-Fired Power Plants” (December 14, 2000), web site www.epa.gov/ttn/oarpg/t3/fact_sheets/fs_util.pdf.

Controlling Emissions of Mercury from Energy Use (Continued)

- The European Union is in the process of developing emissions monitoring procedures and control strategies based on Best Available Technology (BAT) as part of a subsequent directive under the 1996 Air Quality Framework Directive (96/62/EC).

To address transboundary issues related to the long-range transport of mercury emissions, countries are also working under the auspices of the United Nations Environment Programme (UNEP) to develop a global assessment of mercury and its compounds. The assessment, to include options for addressing any significant global adverse impacts of mercury, was presented to the UNEP Governing Council at its 22nd session in February 2003 for further action by the global community. A meeting of UNEP's Working Group on Mercury took place in Geneva, Switzerland, in September 2002 to develop options for addressing global adverse impacts of mercury. Proposals included the creation of an international legally binding treaty to reduce or eliminate mercury use and emissions.[g]

Sample Mercury Limits on Exhaust Gases from Municipal Waste Incineration

Country	Regulated Municipal Waste Process/Technology	Maximum Mercury Concentrations in Exhaust Gases	
		Current	New
Canada	Incineration at 11% oxygen (average)	0.02 mg/m^3	
China	Incineration (average)	0.2 mg/m^3	
Croatia	Incineration with gas flow of 10 g/h or more	1 mg/m^3	
European Union	Incineration at 11% oxygen (average over period of minimum 30 minutes and maximum 8 hours)	0.05 mg/m^3	
Germany	Incineration at 11% oxygen (daily maximum average)	0.03 mg/m^3	
	Incineration at 11% oxygen (half hour average)	0.05 mg/m^3	
Norway	Incineration, facilities permitted after 1994 (average)	0.03 mg/m^3	
South Korea	Incineration (average)	5 mg/m^3	0.1 mg/m3 (January 1, 2005)
United States	Incineration at 7% oxygen (daily maximum)	0.08 mg/m^3	

Source: United Nations Environment Programme, *Global Mercury Assessment. Appendix: Overview of Existing and Future National Actions, Including Legislation, Relevant to Mercury as of November 1, 2002* (Geneva, Switzerland, December 2002), web site www.chem.unep.ch/mercury/Report/Finalreport/final-appendix-1Nov02.pdf.

[g]United Nations Environment Programme, *Global Mercury Assessment* (Geneva, Switzerland, December 2002), web site www.chem.unep.ch/mercury/Report/Finalreport/final-assessment-report-25nov02.pdf.

downwind ozone nonattainment areas. In 1998, the EPA finalized the "Nitrogen Oxides SIP Call" rules, which require 22 States[22] and the District of Columbia to revise their SIPs to control summertime nitrogen oxide emissions. The SIP Call involves a cap and trade program to reduce summertime emissions of nitrogen oxides to target levels beginning in summer 2003 [*23*].[23] After several court challenges, three States[24] were removed from the program, and the compliance date was moved to summer 2004. A similar program in the northeastern States, the NO_x Budget Program, has been reducing emissions through a cap and trade system since 1995. In 2002, States participating in the NO_x Budget Program had reduced their emissions of nitrogen oxides to 60 percent below 1990 levels [*24*].

In December 2003, the EPA released a proposal for regulations controlling both sulfur dioxide and nitrogen oxides in 29 eastern States and the District of Columbia.[25] The Interstate Air Quality proposal would reduce sulfur dioxide emissions within the regulated region by 3.6 million tons in 2010 (a cut of approximately 40 percent from current levels) and by another 2 million tons per year when the rules are fully implemented (a total cut of approximately 70 percent from current levels). Annual nitrogen oxide emissions would be cut by 1.5

[22]Alabama, Connecticut, Delaware, Georgia, Illinois, Indiana, Kentucky, Massachusetts, Maryland, Michigan, Missouri, North Carolina, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, South Carolina, Tennessee, Virginia, Wisconsin, and West Virginia.

[23]Under Section 126 of the Clean Air Act, States may petition the EPA to mitigate significant regional transport of nitrogen oxides. In May 1999, the EPA established the Federal Nitrogen Oxides Budget Trading Program as the general control remedy for reducing interstate ozone transport and required 392 facilities in the Northeast to participate in the cap and trade program for nitrogen oxide emissions.

[24]Georgia, Missouri, and Wisconsin.

[25]Alabama, Arkansas, Connecticut (ozone only), Delaware, Florida (particle pollution only), Georgia, Illinois, Indiana, Iowa, Kansas (particle pollution only), Kentucky, Louisiana, Maryland, Massachusetts, Michigan, Minnesota (particle pollution only), Mississippi, Missouri, New Jersey, New York, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Texas (particle pollution only), Virginia, West Virginia, Wisconsin, and District of Columbia.

Multipollutant Control Legislation in the United States

Electric power plant operators in the United States may face new requirements to reduce emissions of sulfur dioxide, nitrogen oxides, and mercury beyond the levels called for in current regulations. Some proposed Federal legislative initiatives would also require mandatory reduction of carbon dioxide emissions. Whereas in the past each pollutant was addressed through a separate regulatory program, the new legislative initiatives focus on simultaneous reductions of multiple emissions in order to reduce the cost and administrative burden of compliance. The legislative initiatives now being considered would also modify the New Source Review requirements of the 1990 Clean Air Act Amendments for modernization at older power plants.

Three major legislative initiatives were introduced in Congress during the 107th legislative session and have been referred to committee for further consideration. A fourth was announced early in the 108th Congress. Introduced first by Senator Jim Jeffords in 2002 and later in 2003, the Clean Power Act of 2003 is the most far-reaching of the multipollutant initiatives. As shown in the table below, it covers emissions of sulfur dioxide, nitrogen oxides, mercury, and carbon dioxide. The bill proposes a cap and trade scheme for meeting sulfur dioxide, nitrogen oxide, and carbon dioxide emission targets and a MACT requirement to reduce mercury emissions. The current Clean Air Act requires the EPA to adopt a performance standard based on MACT in the next few years, with compliance required by the end of 2007. In addition, the Clean Power Act of 2003 would require every power plant to be equipped with the most recent pollution controls required for new sources by the plant's 40th year of operation or by 2014, whichever is later.

The Clear Skies Initiative, announced by President Bush in February 2002 and introduced as House and Senate bills, proposes nationwide caps for sulfur dioxide and mercury and regional (East and West) caps for nitrogen oxides. The Clear Skies Initiative differs from the proposed Clean Power Act primarily in targeted emission reductions and proposed compliance dates. The final nitrogen oxides and sulfur dioxide targets are close to those proposed in the Clean Power Act of 2003, but mercury reductions are not as stringent, and the timetable for reaching the targets is delayed by 5 to 10 years, depending on the pollutant. The Clear Skies

(continued on page 153)

Key U.S. Legislative and Policy Initiatives for Multipollutant Control

Proposal Title	Sponsor	Annual Nitrogen Oxides (NO_x) (Million Tons)	Annual Sulfur Dioxide (SO_2) (Million Tons)	Annual Mercury (Hg) (Tons)	Annual Carbon Dioxide (CO_2) (Million Metric Tons)
		Current Emission Levels from Fossil-Fueled Electricity Generation[a]			
		4.7 (2001)	10.6 (2001)	48 (2000)	2,044 (1990); 2,249 (2000)
		Proposed Reduction Goals and Timetable[b]			
Clear Skies Initiative (S. 1844)[c]	Bush Administration	2.1 million tons in 2008; 1.7 million tons in 2018	4.5 million tons in 2010; 3.0 million tons in 2018	34 tons in 2010; 15 tons in 2018	Voluntary
Clean Power Act of 2003 (S. 366)	James Jeffords (I-VT)	1.5 million tons by 2009	2.25 million tons by 2009	5 tons by 2009; 2.48 g/GWhr MACT in 2008	2,050 million metric tons by 2009
Clean Air Planning Act of 2003 (S. 843)	Tom Carper (D-DE)	1.51 million tons by 2009; 1.70 million tons by 2013	4.50 million tons by 2009; 3.50 million tons in 2013; 2.25 million tons in 2016	24 tons by 2009; 10 tons by 2013	2006 level by 2009; 2001 level by 2013
Greenhouse Gas Cap and Trade	John McCain (R-AZ) and Joseph Lieberman (D-CT)	—	—	—	2000 level by 2010[d] 1990 level by 2016

[a]Sources: Energy Information Administration, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), for data on nitrogen oxides, sulfur dioxide, and carbon dioxide. Data on mercury obtained from Congressional Research Service, *Air Quality: Multi-Pollutant Legislation*, CRS Report No. RL31326 (Washington, DC, October 22, 2002).

[b]Source: Resources for the Future, "Legislative Comparison of Multipollutant Proposals S. 366, S. 1844, and S. 843. Version 01/22/2004," web site www.rff.org/multipollutant.

[c]S. 1844 was sponsored by Senator James Inhofe in November 2003. The exact emissions reductions differ somewhat from those proposed in the Bush Administration's original Clear Skies Initiative; however, the Administration has proposed regulatory rules similar to the provisions of S. 1844.

[d]Emissions of all six greenhouse gases would be covered (carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride), and allowances would be traded in metric tons carbon dioxide equivalent. The bill would cover the transportation, industrial, and commercial sectors in addition to electricity generation.

Multi-Pollutant Legislation in the United States (Continued)

Initiative provides for market-based cap and trade programs for nitrogen oxides and sulfur dioxide and also provides for mercury emissions trading. It includes carbon dioxide emission provisions that would be voluntary only.

The third bill, the Clean Air Planning Act of 2003, was introduced by Senator Tom Carper in October 2002 and later in April 2003. Its emissions targets are generally between those of the Clean Power Act and those of the Clear Skies Initiative. The Clean Air Planning Act would establish caps on emissions of sulfur dioxide, nitrogen oxides, and mercury, but they would be phased in over a longer period than proposed in the Clean Power Act. The bill would also introduce limited caps on carbon dioxide emissions. The bill proposes to reduce carbon dioxide emissions to 2006 levels by 2009 and to 2001 levels by 2013, whereas the Clean Power Act would reduce carbon dioxide emissions to 1990 levels by 2009. The nitrogen oxide, sulfur dioxide, and mercury reduction targets and timelines included in the legislation are more aggressive than those outlined in the President's Clear Skies Initiative but less stringent than those proposed in the Clean Power Act.

In early January 2003, Senators McCain and Lieberman introduced legislation to reduce annual emissions of greenhouse gases by emitters in the electricity, transportation, industrial, and commercial sectors that produce 10,000 metric tons carbon dioxide or more per year.[a] The bill would create a system of tradable allowances allocated to emitters in each sector free of charge, with the goal of reducing greenhouse gas emissions to 2000 levels by 2010 and to 1990 levels by 2016. It does not address emissions of nitrogen oxides, sulfur dioxide, or mercury.

[a]U.S. Senator Joseph Lieberman, "Summary of Lieberman/McCain Draft Proposal on Climate Change," Press Release (Washington, DC, January 8, 2003), web site www.senate.gov/~lieberman/press/03/01/2003108655.html.

million tons in 2010 and 1.8 million tons in 2015 (a reduction of approximately 65 percent from current levels). Emissions of both pollutants would be permanently capped. The EPA is accepting public comment on the Interstate Air Quality proposal, and issuance of a final rule is planned for 2005 [*25*].

Also in December 2003, the EPA proposed a Utility Mercury Reductions rule. When implemented, it will be the first U.S. regulatory program to control mercury emissions from electricity generators. The proposed rule, using a cap and trade system, would cut mercury emissions by 70 percent after 2018, when Phase II is implemented and allowances banked before 2018 have been exhausted. The EPA is seeking comments on two proposals to reduce mercury emissions, one based on MACT and another based on a cap and trade system. The MACT approach would reduce annual mercury emissions by 14 tons (29 percent) by 2007 [*26*].

In addition to the EPA programs and initiatives discussed above, several legislative proposals introduced recently in the U.S. Congress are aimed at simultaneous reductions of multiple emissions, including sulfur dioxide, nitrogen oxides, mercury, and/or carbon dioxide (see box above).

Canada

In Canada, emissions from stationary sources are regulated under the Thermal Power Generation Emissions National Guidelines for New Stationary Sources of the 1993 Canadian Environmental Protection Act (CEPA). In January 2003, the emission guidelines for new sources of electricity generation were updated, tightening emissions limits for sulfur dioxide, nitrogen oxide, and particulate matter from new coal-, oil-, and natural-gas-fired steam-electric power plants [*27*]. The new targets would lower sulfur dioxide emissions by 75 percent, nitrogen oxide emissions by 60 percent, and emissions of particulate matter by 80 percent. With these requirements, the long-term emission performance of all fossil-fired generation is targeted to approach that of natural gas.

Additional efforts to abate sulfur dioxide emissions have focused on the seven easternmost provinces, where smog levels are on the rise and acid rain is a concern.[26] The Eastern Canada Acid Rain Program placed a region-wide cap on sulfur dioxide emissions at 2.3 million metric tons per year for 1994, mostly by restricting emissions from large industrial facilities. Recently, new measures at provincial levels were enacted to reduce nitrogen oxide emissions. Starting in 2007, fossil-fueled power plants in central and southern Ontario will face an annual cap of 39,000 tons, and emissions from plants in southern Quebec will be capped at 5,000 tons.

Addressing the problems of acid rain and ground-level ozone in Canada has required cooperation with the United States, given the transboundary flow of air

[26]The seven Canadian provinces covered under the Eastern Canada Acid Rain Program are Manitoba, Ontario, Quebec, New Brunswick, Nova Scotia, Newfoundland, and Prince Edward Island.

pollutants between the two countries. The Canada-U.S. Air Quality Agreement, signed in 1991, has been amended to include additional pollutants over the past 13 years. In December 2000, one such annex set a target of cutting ozone in the U.S./Canada transboundary region by 43 percent by 2010 [***28***]. The agreement was seen as a major step toward harmonizing air quality standards for stationary and mobile sources, and negotiators have begun discussing its expansion to cover other pollutants.

Canadian regulation of mobile sources tends to mirror standards in the United States, in line with efforts to create an integrated vehicle manufacturing market in North America. Starting with the 1998 model year, regulations for light-duty vehicles were aligned with the Tier 1 standards of the United States. According to a regulation introduced in January 2003, standards for passenger cars, minivans, pickup trucks, sport utility vehicles, heavy-duty trucks and buses, and motorcycles will be subject to more stringent emissions standards [***29***].

In 1999, Canada approved a limit of 30 parts per million sulfur content in gasoline, which would take effect by January 1, 2005. The average level of sulfur in Canadian gasoline is currently 150 parts per million. Canada will also require a diesel fuel sulfur cap of 15 parts per million by June 2006, mirroring the U.S. highway diesel regulation.

Mexico

Air pollution in the large cities of Mexico is a serious concern for the country. Mexico City, Guadalajara, and Ciudad Juarez are the most polluted, and Mexico City's air quality is among the worst in the world. In addition to pollution from industrial sources, the transportation sector is a major source of emissions, accounting for 80 percent of the country's nitrogen oxide emissions, 40 percent of volatile organic compound emissions, 20 percent of sulfur dioxide, and 35 percent of small particulate matter emissions [***30***].

In the 1990s, the Mexican government implemented a number of policies that dramatically improved air quality in the Mexico City area. Catalytic converters were required for all new cars beginning in 1991, and leaded gasoline was eliminated by 1997. The government has also reduced the concentration of sulfur in diesel, introduced oxygenates into gasoline, enhanced emissions inspection programs, and introduced LPG and compressed natural gas (CNG) as alternative vehicle fuels. A "No Driving Day" (Hoy No Circula) program, introduced in the greater Mexico City region in 1989, banned 20 percent of registered cars from driving in the city on one workday of each week, rotating the ban based on the last digit of vehicle license plate numbers. The program continued throughout the 1990s but became less effective as people began to acquire two cars to avoid the regulation. In 1999 it was recast to allow cars equipped with emissions control systems equivalent to U.S. Tier 1 limits to drive on any day of the week, and stricter driving limits (No Driving for Two Days) were placed on cars without the updated technology [***31***].

In addition to transportation, electricity generation from the two power plants in the Mexico City metropolitan area is a major source of air pollution. In 1986 the two plants switched from high-sulfur fuel oil to natural gas, significantly reducing sulfur dioxide emissions in the region. The plant operators have also installed new pollution control technology, improved maintenance programs, and implemented continuous stack monitoring systems [***32***]. More recently, operators have begun switching generating units in one of the power plants to combined-cycle generation, which will further reduce nitrogen oxide emissions while meeting the growing demand for electricity. Despite the improvements made recently, both power plants near Mexico City are aging, and rising maintenance and administrative costs may limit the extent to which their emissions can be reduced [***33***].

European Union

In Europe, efforts to limit aggregate emissions of sulfur dioxide, nitrogen oxides, volatile organic compounds, and particulate matter were first coordinated under the 1979 United Nations/European Economic Commission's Convention on Long-Range Transboundary Air Pollution (CLRTAP), which was drafted after scientists demonstrated the link between sulfur dioxide emissions in continental Europe and the acidification of Scandinavian lakes. Since its entry into force, the Convention has been extended by eight protocols that set emissions limits for a variety of pollutants. The 1999 Gothenburg Protocol calls for national emissions ceilings for sulfur dioxide, nitrogen oxides, volatile organic compounds, and ammonia in 2010.

The establishment of national emission ceilings is a regulatory innovation in air pollution control in the EU, in that the different emissions ceilings are tailored to meet country-specific circumstances and allow member countries flexibility in implementing control measures. As with previous CLRTAP protocols, the Gothenburg Protocol specifies tight limit values for specific emissions sources and requires best available technologies to be used to achieve the emissions reductions. Once the Protocol is fully implemented, Europe's sulfur emissions should be cut by about 75 percent, nitrogen oxide emissions by almost 50 percent, emissions of volatile organic compounds by about 55 percent, and ammonia emissions by 15 percent from their 1990 levels. As of December 5, 2003, however, only Denmark, Luxembourg, Norway, Romania, the European Community, and Sweden had ratified the Gothenburg Protocol [*34*].

While CLRTAP addresses both stationary and mobile sources, another EU directive on the Limitation of Emissions of Certain Pollutants into the Air from Large Combustion Plants (Directive 2001/80/EC0) was passed in late 2001 targeting only stationary combustion. This directive amended the Large Combustion Plant Directive of 1988 (Directive 88/609/EEC), which imposed emissions limits for sulfur dioxide, nitrogen oxides, and dust on existing and new power plants with a rated thermal input capacity greater than 50 megawatts. For plants licensed before July 1, 1987, the 1988 directive placed a gradually declining ceiling (cap) on total annual emissions of each pollutant. The ceiling values differed by country. The directive did not stipulate how the emissions reductions were to be achieved, although the general approach used by several European countries has been to require the use of specific emissions control technologies and combustion fuels. All plants licensed after July 1, 1987, faced uniform emissions limit values, which were set according to plant capacity, size, and fuel type.

The new directive was seen as a package deal, along with CLRTAP, toward the development of a comprehensive EU strategy to deal with acidification. The directive takes into account advances in combustion and abatement technologies and reduces the nitrogen oxides limit values for large solid fuel plants from 650 milligrams per cubic meter to 200 milligrams per cubic meter. This limit, which applies to both new and existing plants from 2016 onward, will be a crucial benchmark in the forthcoming negotiations with Eastern European candidate countries hoping to enter the EU. However, existing plants may be exempt from obligations concerning new emissions standards if they are operated for less than 20,000 hours between January 2008 and December 2015. The directive does provide member countries with some flexibility in terms of specifying control technologies but, unlike the U.S. regulatory scheme, does not include provisions for market-based emission reductions, such as allowance trading.

Emissions from motor vehicles have been regulated in Europe since the 1970 Motor Vehicle Directive. The most stringent vehicle emission limits were passed in 1998 and 1999 by Directives 98/69/EC and 99/96/EC. As the law currently stands, all new vehicles must meet the “Euro 3” emissions standards for carbon monoxide, hydrocarbons, and nitrogen oxides by 2000 and 2001, depending on weight class. Between 2005 and 2008, the tighter Euro 4 and Euro 5 standards for new vehicles will take effect. Germany, the Netherlands, Belgium, and the United Kingdom have encouraged the switch to low-sulfur gasoline and diesel by offering tax incentives. Sweden already requires “city diesel” to meet the same sulfur standard (50 parts per million) required by the EU in 2005. The EU recently finalized regulations that include the mandatory introduction of sulfur-free gasoline and diesel fuels, with sulfur levels lower than 10 milligrams per kilogram, by January 1, 2005, and a complete ban on all non-sulfur-free fuels by January 1, 2009 [*35*]. The implementation of the measure would coincide with the introduction of Euro 4 vehicles in the European market.

Hungary

Hungary submitted its application for EU membership in 1994 and signed the EU Ascension Treaty in April 2003. It is expected to become a member of the EU in May 2004. Many of Hungary’s energy and environmental policies have focused on bringing regulations in line with EU standards. For instance, an energy tax and an environmental tax (with air, water, and soil pollution provisions) were introduced in January 2004. The energy tax, which targets only nonresidential entities, is designed to encourage energy-saving practices. The air pollution provision of the environmental tax, beginning at 40 percent of the proposed final tax rate, will also target companies and will be levied on emissions of carbon dioxide, nitrogen oxides, sulfur dioxide, and particulate matter. The rate of the environmental tax will rise each year until it reaches the desired level in 2008. The energy and environment taxes are expected to generate about $50 million in revenue for the Hungarian government [*36*].

In 1973, Hungary generated more than 65 percent of its electricity from coal-fired power plants, many of which used lignite coal, a relatively low-grade coal with many impurities. As of 2000, however, only about 28 percent of the country’s electric power came from coal-fired power plants, and more than 40 percent came from nuclear facilities. Much of the growth in electricity demand from 1973 to 2000 was met with nuclear and, to a smaller extent, natural-gas-fired generation. The diversity of its fuel mix has helped improve Hungary’s environment, with total sulfur dioxide pollution falling from more than 800,000 tons in 1992 to less than 600,000 tons in 1998 [*37*]. Although sulfur dioxide emissions have been falling, they are greater, on a per capita basis, than the EU average, probably because of the continued use of lignite for power generation.

Developing Countries

While emissions of sulfur dioxide, nitrogen oxides, and particulate matter have either declined or slowed in most industrialized countries, many developing countries are seeing rapid growth in energy-related pollution. The most pressing problems are growing sulfur dioxide emissions and acid rain from coal-fired power plants and increasing levels of smog and particulate matter in urban areas from both transportation and power generation. To address these environmental problems, many developing countries have introduced regulations targeting motor vehicle use and coal-fired power generation; however, compliance with emissions regulations is often low in developing countries, where funding may be limited and enforcement inadequate [*38*]. Thus, in the face of strong population growth and economic development, emissions of air pollutants in urban centers of the developing world have increased steadily.

China

Many cities across China suffer from air pollution problems. In 2003, 63 percent of the 330 Chinese cities being monitored had poor air quality [*39*]. One of the main pollutants is sulfur dioxide, resulting in the formation of acid rain, which now falls on about 30 percent of China's total land area [*40*]. About 34 percent (6.6 million tons) of the country's total sulfur dioxide emissions in 2002 were released from power plants [*41*]. Because more than 70 percent of China's electricity comes from coal-fired plants, the country faces a challenge in providing adequate supplies of electricity while trying to reduce sulfur dioxide emissions, particularly near major cities [*42*]. Given that rolling blackouts were a feature of China's electricity markets in 2003, the difficulties are sure to mount in the future.

China has implemented a new coal policy, which is expected to reduce sulfur dioxide emissions in 2005 by 10 percent from 2000 levels nationwide and by 20 percent in "control zones" with high pollution, including Beijing, Shanghai, Tianjin, and 197 other cities [*43*]. The control zones account for only 11.4 percent of China's land area but for 66 percent of the 20 million tons of sulfur dioxide emitted each year. The new policy increases the pollution levy to 5 yuan (60.4 cents) per ton and requires power companies and large industrial facilities to install desulfurization equipment [*44*]. Smaller facilities must use low-sulfur coal or cleaner fuel alternatives.

In addition, pilot sulfur dioxide emissions trading programs are underway in Benxi (Liaoning Province) and Nantong (Jiangsu Province), and in early 2002 the State Environmental Protection Administration (SEPA) announced that the provinces of Shandong, Shanxi, Henan, and Jiangsu, the special administrative regions of Macau and Hong Kong, and three cities (Shanghai, Tianjin, and Liuzhou) would pioneer China's first emissions trading scheme across provincial borders near the end of the decade. Officials hope to establish rules for emissions trading by 2006.

Although point sources are a major source of both sulfur dioxide and particulate matter in China, mobile sources in major cities account for an increasing percentage of the country's air pollution. For instance, city planners in Shanghai estimate that about 90 percent of the city's air pollution is from vehicle traffic [*45*]. The number of vehicles in China has increased considerably in recent years. In Beijing, vehicle ownership has risen from 1 million in 1997 to 2 million in 2003, and during 2003 new vehicles were coming onto Beijing's roads at a rate of 27,000 per month [*46*]. The crowd of vehicles on the road has exacerbated traffic to the extent that average rush hour speeds in certain parts of Beijing are less than 7 miles per hour [*47*].

Shanghai has developed programs to limit the number of drivers in the city, including charging registration fees for new vehicles valued at more than $4,000 [*48*]; however, Beijing is not prepared to take such measures to limit cars on the roads and instead is building more roads and expanding the public transportation system in the city. In a measure that will help reduce pollution from existing vehicles, cars in Beijing will have to meet European emissions standards as of summer 2004. In an additional effort to reduce air pollution, the Beijing municipal government has converted more than 1,900 municipal buses to liquefied petroleum gas and plans to increase the number to 18,000 by 2008 [*49*].

Beijing and Shanghai have a strong incentive to improve air quality over the next 5 to 6 years: Beijing will host the 2008 Olympics, and Shanghai will host the 2010 World Expo. Some progress has already been made. In 2003, Beijing had 219 days of "satisfactory" air quality, compared with only 100 in 1998 [*50*]. Still, the concentration of small particulate matter in Beijing's air is 65 micrograms per cubic meter higher than China's national standard of 100 micrograms per cubic meter. In the United States, a value of 165 micrograms per cubic meter would be "code red," and the EPA would recommend that people reduce heavy or prolonged exertion [*51*].

India

Urban air quality in India ranks among the world's poorest [*52*]. Efforts to improve urban air quality have focused on vehicles, which account for the majority of the country's air pollution. Emissions limits for gasoline- and diesel-powered vehicles came into force in 1991 and 1992, respectively. Emissions standards for passenger cars and commercial vehicles were tightened in 2000 at levels equivalent to the Euro 1 standards. For the metro areas of Delhi, Mumbai, Chennai, and Kolkata, tighter Euro 2 standards have been required since 2001. In October 2003, the Indian government introduced new standards for automotive fuel and vehicle emissions, including a ban on sales of vehicles that do not meet Euro 3 emissions standards by 2010, a similar but earlier (April 2005) ban in 11 major cities, and a 2010 requirement that new vehicles in those 11 cities (including New

Delhi) meet the stringent Euro 4 emissions standards [*53*].

The measures taken to reduce vehicle emissions in New Delhi have been more controversial. In 1998, India's Supreme Court mandated a number of measures to improve the city's air quality. One such measure stipulated that all the city's buses be run on CNG by March 31, 2001. Compliance was to be achieved either by converting existing diesel engines or by replacing the buses themselves. The conversion of the fleet had not been achieved as the deadline approached, and rather than paralyze the transportation system with a shutdown of bus service, the courts extended the deadline to September 2001 and then to January 2002 [*54*]. During the additional period, diesel buses could remain on the road if their owners demonstrated that they had placed an order for a replacement or conversion to CNG. Although difficult for many bus owners during the conversion period, the program increased the number of CNG buses in New Delhi from 900 in May 2001 to about 6,800 in mid-2002, an increase of more than 650 percent. One challenge with the swift conversion of the fleet has been a number of safety issues with CNG buses, which the government continues to address.

Buses were not the only vehicles converted to run on CNG. More than 27,000 automobiles and 14,000 other vehicles were also running on CNG by mid-2002 [*55*]. Many reporters have anecdotally described the improvements in air quality over the 2000-2002 period, during which many diesel vehicles were removed from circulation.

In other cities in India, emissions from diesel buses are eclipsed by those from "auto rickshaws" with 2-stroke and 4-stroke engines. Many rickshaw drivers concoct their own fuel, a mix of kerosene and engine lubricant that releases pollution as the fuel burns. Some cities in India (for instance, Ahmedabad) are looking into the possibility of converting existing auto rickshaws to run on LPG, a much cleaner fuel. The overhead of converting the rickshaws would be difficult for individual owners to finance, even though the lower cost of LPG can save money over the long term. Currently, proponents of the plan are looking for funding to help with the conversion of the 65,000 rickshaws on the streets of Ahmedabad [*56*].

Although India is a large coal consumer, its Central Pollution Control Board has not set any sulfur dioxide emissions limits for coal-fired power plants, because most of the coal mined in India is low in sulfur content. Coal-fired power plants do not face any nitrogen oxide emissions limits either, although thermal plants fueled by natural gas and naphtha face standards between 50 and 100 parts per million, depending on their capacity. Enforcement of the standards has been recognized as a major problem in India [*57*].

Chile

Chile's capital city, Santiago, is among the most polluted in the Western Hemisphere. Santiago, a city of 5.5 million people, is situated between two mountain ranges. In winter (June-August), when prevailing winds off the Southern Pacific Ocean lessen, cool air from the mountains traps polluted air in the city. For at least the past 5 years, Santiago has undergone a number of "environmental pre-emergencies," in which the concentration of particulate matter in the air exceeded 240 micrograms per cubic meter. (An "environmental emergency" is declared when the concentration of particulate matter reaches 330 micrograms per cubic meter [*58*].) For example, a pre-emergency was declared in May 2003, when the concentration of particulate matter in the air increased to more than 300 micrograms per cubic meter [*59*].

When the government declares an environmental pre-emergency, measures to reduce pollution immediately are put into effect. The volume of traffic in the city is limited by banning 60 percent of vehicles without catalytic converter technology from the roads as well as 20 percent of the cars that do have catalytic converters. Additionally, nearly a thousand high-pollution manufacturing plants may also be shut down, a move that could strain the city's economy if there are a large number of shutdowns each winter [*60*]. In the United States, a level of 240 micrograms per cubic meter would be considered extremely hazardous, and the EPA would recommend that older adults, children, and persons with chronic illness stay inside, and that all others avoid activity outside [*61*].

Santiago is pursuing a number of environmental policies designed to reduce the level of particulate matter in the air. One approach seeks to reduce the concentration of pollutants in the air through direct regulation, another program to introduce CNG as a fuel for buses in Santiago, and another to reduce air pollution by changing traffic patterns and increasing the average speed of vehicles in the city during peak hours.

Santiago is reducing direct emissions from both point sources and mobile sources. Fixed emitters were subject to more stringent regulations as of 1998, when the maximum allowable concentration of particle emissions was lowered from 112 micrograms per cubic meter to 56 micrograms per cubic meter [*62*]. The city is also trying to reduce pollution from mobile sources, especially heavier vehicles that use diesel, by changing the fuel types available in the city. The Santiago region switched to a low-sulfur diesel fuel (300 parts per million sulfur) at the beginning of 2001 and will be reducing the sulfur limit for diesel to 50 parts per million in July 2004.

Over the past 10 years, Santiago has been working on modernizing its bus fleet. In the mid-1990s, Chile's government bought a number of high-emissions diesel buses from private bus operators in Santiago—a measure that succeeded in removing the most polluting buses from the city's streets but at considerable expense [*63*]. More recently, Santiago has worked with the U.S. Department of Energy's Clean Cities program to switch a number of buses and taxis to CNG [*64*]. If the process of removing polluting diesel buses from the streets continues, it can make a major contribution toward reducing particulate matter pollution in Santiago.

Santiago has also instituted a number of policies designed to keep more traffic moving freely during peak travel times, which would also reduce emissions of particulate matter. By making some streets one-way during peak times, the city can handle its regular volume of traffic more easily. Although it may serve as a short-term solution, over time the excess road capacity may prove counterproductive, in that will provide an incentive for more people to drive to work [*65*].

References

1. United Nations, *United Nations Framework Convention on Climate Change* (1992), Article 2, "Objective," p. 9, web site http://unfccc.int/resource/docs/convkp/conveng.pdf.
2. United Nations Framework Convention on Climate Change, "Greenhouse Gas Inventory Database," web site http://ghg.unfccc.int.
3. United Nations Framework Convention on Climate Change. "Kyoto Protocol: Status of Ratification," web site http://unfccc.int/resource/kpstats.pdf.
4. R.G. Newell, J.N. Sanchirico, and S. Kerr, "Fishing Quota Markets," Resources for the Future Discussion Paper 02-20 (August 2002).
5. Official Journal of the European Union, *Directive 2003/87/EC of the European Parliament and of the Coucil of 13 October 2003: establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96-61-EC*, web site http://europa.eu.int/eur-lex/pri/en/oj/dat/2003/l_275/l_27520031025en00320046.pdf.
6. United Nations Environmental Programme, *An Emerging Market for the Environment: A Guide to Emissions Trading* (Denmark: UNEP Collaborating Centre on Energy and the Environment, UN Conference on Trade and Development, 2002).
7. S.L. Pedersen, "Danish CO_2 Cap & Trade Scheme: Function and Experiences," presented at the SERC Workshop, Tokyo, Japan (December 3, 2002), web site www.ens.dk/graphics/ENS_Forsyning/Kvoter/dk_etr_291002.pdf.
8. S.L. Pedersen, "Danish CO_2 Cap & Trade Scheme: Function and Experiences," presented at the SERC Workshop, Tokyo, Japan (December 3, 2002), web site www.ens.dk/graphics/ENS_Forsyning/Kvoter/dk_etr_291002.pdf.
9. U.K. Department for Environment, Food, and Rural Affairs, *A Summary Guide to the UK Emissions Trading Scheme*, web site www.defra.gov.uk/environment/climatechange/trading/pdf/trading-summary.pdf.
10. U.K. Department for Environment, Food, and Rural Affairs, *Commentary on Preliminary First Year results and 2002 Transaction Log*, web site www.defra.gov.uk/environment/climatechange/trading/pdf/ets-commentary-yr1.pdf.
11. F. Lecocq and K. Capoor, "State and Trends of the Carbon Market 2003" (December 1, 2003), web site http://carbonfinance.org.
12. Evolution Markets LLC, "Evolution Markets Brokers Sale of Carbon Credits Between Hungarian Power Producer and the Dutch Government" (Press Release, December 16, 2003), web site www.evomarkets.com; and Prototype Carbon Fund, "Frequently Asked Questions," web site http://carbonfinance.org.
13. F. Lecocq and K. Capoor, "State and Trends of the Carbon Market 2003" (December 1, 2003), web site http://carbonfinance.org.
14. J.D. Kilgroe, C.B. Sedman, R.K. Srivastava, J.V. Ryan, C.W. Lee, and S.A. Thorneloe, *Control of Mercury Emissions from Coal-Fired Electric Utility Boilers: Interim Report*, EPA-600/R-01-109 (Research Triangle Park, NC, December 2001), web site www.epa.gov/ordntrnt/ORD/NRMRL/Pubs/600R01109/600R01109.htm.
15. European Environment Agency, *Environmental Signals 2000: Environmental Assessment Report No. 6* (Copenhagen, Denmark, May 2000), web site http://reports.eea.eu.int/signals-2000/en.
16. U.S. Environmental Protection Agency, *Latest Findings on National Air Quality: 2001 Status and Trends*, EPA 454/K-02-001 (Research Triangle park, NC, September 2002), web site www.epa.gov/airprogm/oar/aqtrnd01/summary.pdf.
17. International Fuel Quality Center, *Current Status of Leaded Gasoline Phase Out Worldwide* (February 4, 2003) (updated by personal communication, October 30, 2003).
18. M. Lovei, *Phasing Out Lead From Gasoline: Worldwide Experience and Policy Implications*,World Bank Technical Paper No. 397 (Washington, DC, 1998), p. 2.
19. United Nations Environmental Program—Chemicals, *Global Mercury Assessment* (December 2002),

web site www.chem.ch/mercury/Report/GMA-report-TOC.htm.

20. United Nations Environment Programme, *Report of the Global Mercury Assessment Working Group on the Work of Its First Meeting*, UNEP(DTIE)/MGA/WG.1/8 (Geneva, Switzerland, September 2002).

21. U.S. Environmental Protection Agency, *Latest Findings on National Air Quality: 2002 Status and Trends*, EPA 454/K-03-001 (Research Triangle park, NC, August 2003), web site www.epa.gov/airprogm/oar/aqtrnd01/summary.pdf.

22. U.S. Environmental Protection Agency, *Nitrogen Oxides (NOx) Reduction under Phase II of the Acid Rain Program*, web site www.epa.gov/airmarkets/arp/nox/phase2.html.

23. U.S. Environmental Protection Agency, "Fact Sheet: The Federal NO_x Budget Trading Program," web site www.epa.gov/airmarkets/fednox/fnbtp-fact.pdf.

24. Ozone Transport Commission, *NO_x Budget Program: 1999-2002 Progress Report* (March 2003), web site www.epa.gov/airmarkets/otc/otcreport.pdf.

25. U.S. Environmental Protection Agency, "Interstate Air Quality Rule," web site www.epa.gov/interstateairquality.

26. U.S. Environmental Protection Agency, "Clean Air Proposals Promise Sharp Power Plant Pollution Reductions" (Press Release, December 15, 2003).

27. Government of Canada, "News Release: Government of Canada Tightens Emission Guidelines for New Electricity Plants" (Ottawa, January 3, 2003).

28. Government of Canada, "News Release: Canada and the United States Embark on New Era of Cleaner Air" (December 7, 2000), web site www.ec.gc.ca/press/001207_n_e.htm.

29. Environment Canada "Clean Air in Canada: 2003 Progress Report on Particulate Matter and Ozone," web site www.ec.gc.ca/air/PM_resp_03/s2_e.html#1.

30. L.T. Molina and M.J. Molina, eds., *Air Quality in the Mexico Megacity: An Integrated Assessment* (Boston, MA: Kluwer Academic Publishers, 2002), p. 213.

31. L.T. Molina and M.J. Molina, eds., *Air Quality in the Mexico Megacity: An Integrated Assessment* (Boston, MA: Kluwer Academic Publishers, 2002), pp. 333-334.

32. L.T. Molina and M.J. Molina, eds., *Air Quality in the Mexico Megacity: An Integrated Assessment* (Boston, MA: Kluwer Academic Publishers, 2002), p. 90.

33. L.T. Molina and M.J. Molina, eds., *Air Quality in the Mexico Megacity: An Integrated Assessment* (Boston, MA: Kluwer Academic Publishers, 2002), p. 91.

34. United Nations Economic Commission for Europe, "Status of Ratification of the 1999 Gothenburg Protocol To Abate Acidification, Eutrophication and Ground-level Ozone as of 5 December 2003," web site www.unece.org/env/lrtap/status/99multi_st.htm.

35. European Union, "Parliament and Council Reach Agreement on Sulphur-Free Fuels" (December 12, 2002), web site www.euractiv.com/.

36. World Markets Research Centre, "Hungary: 2004 Brings Extra Tax Burden to Hungarian Energy Sector" (January 13, 2004).

37. International Energy Agency, *Energy Policies of IEA Countries: Hungary 2003 Review* (Paris, France, 2003).

38. M. Kojima and M. Lovei, *Urban Air Quality Management: Coordinating Transport, Environment, and Energy Policies in Developing Countries*, World Bank Technical Paper No. 508 (Washington, DC, September 2001), p. 17.

39. "$103b in Losses Due to Power Plants Acid Rain," *South China Morning Post* (October 11, 2003).

40. "$103b in Losses Due to Power Plants Acid Rain," *South China Morning Post* (October 11, 2003).

41. "$103b in Losses Due to Power Plants Acid Rain," *South China Morning Post* (October 11, 2003).

42. "China's Electricity Crisis Puts Coal Back in Fashion," *World Gas Intelligence* (December 8, 2003).

43. N.J. Smith, "China OKs Plan for Tackling Sulfur Dioxide with Added Emphasis on Emissions Trading," *BNA International Environment Reporter*, Vol. 25, No. 24 (November 20, 2002).

44. "China – Emissions Plan Set to Expand" *China Daily* (November 19, 2002).

45. "The Environment—The Great Car Crush: Unless China Can Cope With Cars, It Has a Crisis in the Making," *Far Eastern Economic Review* (November 27, 2003).

46. "One in Four Beijingers Now Owns a Car," *South China Morning Post* (August 6, 2003).

47. "The Environment—The Great Car Crush: Unless China Can Cope With Cars, It Has a Crisis in the Making," *Far Eastern Economic Review* (November 27, 2003).

48. "The Environment—The Great Car Crush: Unless China Can Cope With Cars, It Has a Crisis in the Making," *Far Eastern Economic Review* (November 27, 2003).

49. "The Greening of China: As the Economy Has Grown, So Have Waste and Pollution. But There's Big Money in Repairing the Environment," *Business Week* (October 27, 2003).

50. "Beijingers Enjoy More Blue-Sky Days This Year," *Xinhua News Agency* (December 20, 2003).

51. U.S. Environmental Protection Agency, "Air Quality Index: A Guide to Air Quality and Your Health," web site www.epa.gov/airnow/aqibroch/aqi.html#aqipar.

52. "Smoking Cities," *BBC News Online* (January 25, 1999), web site news.bbc.co.uk.

53. World Market Research Centre, "India Unveils New Emissions Regulations To Combat Air Pollution" (October 7, 2003).

54. L. Erlandsson and C. Weaver, *Safety of CNG Buses in Delhi: Findings and Recommendations* (Centre for Science and Environment, August 9, 2002).

55. "A Firm Court Clears the Air," *New Straits Times Press* (March 4, 2003).

56. "LPG Plan for Rickshaws Could Clear Air of Toxins," *The Times of India* (August 23, 2003).

57. S. Sinha, "Environmental Guidelines for Power Plants in India and Other Nations," *Environmental Quality Management*, Vol. 11, No. 1 (Autumn 2001), pp. 57-69.

58. J.-P. Montero, J.M. Sanches, and R. Katz, "A Market-Based Environmental Policy Experiment in Chile," *Journal of Law and Economics*, Vol. 45, No. 1 (April 2002).

59. EFE News Service, "Air Pollution Reaches Dangerous Levels in Santiago" (May 19, 2003).

60. EFE News Service, "Air Pollution Reaches Dangerous Levels in Santiago" (May 19, 2003).

61. U.S. Environmental Protection Agency, "Air Quality Index: A Guide to Air Quality and Your Health," web site www.epa.gov/airnow/aqibroch/aqi.html#aqipar.

62. Economist Intelligence Unit Riskwire, "Chile Risk: Infrastructure Risk" (May 30, 2003).

63. "The Right To Drive or the Right To Breathe?", *The Economist* (March 7, 2002).

64. J. Parada, "Current Situation and Perspectives of the Clean Cities Program in Santiago, Chile" (Clean Cities Program, U.S. Department of Energy, October 2001).

65. "Today's Other News in Brief: Bus Union Calls Off Strike, State Calls Traffic Plan a Hit," *Santiago Times* (April 16, 2002).

Appendix A

Reference Case Projections:

- World Energy Consumption
- Gross Domestic Product
- Carbon Dioxide Emissions
- World Population

Table A1. World Total Primary Energy Consumption by Region, Reference Case, 1990-2025
(Quadrillion Btu)

Region/Country	History 1990	History 2000	History 2001	Projections 2010	Projections 2015	Projections 2020	Projections 2025	Average Annual Percent Change, 2001-2025
Industrialized Countries								
North America	**100.6**	**118.7**	**115.6**	**134.5**	**144.6**	**155.0**	**166.6**	**1.5**
United States[a]	84.6	99.3	97.0	111.8	119.7	127.9	136.5	1.4
Canada	11.0	13.2	12.5	15.4	16.5	17.5	18.4	1.6
Mexico	5.0	6.2	6.0	7.3	8.3	9.6	11.6	2.8
Western Europe	**59.9**	**66.8**	**68.2**	**71.2**	**73.8**	**76.7**	**79.7**	**0.7**
United Kingdom	9.3	9.8	9.8	10.3	10.8	11.2	11.7	0.7
France	8.8	10.4	10.5	11.8	12.3	12.9	13.4	1.0
Germany	14.8	14.2	14.4	14.8	15.1	15.5	15.9	0.4
Italy	7.0	8.0	8.1	8.5	8.8	9.2	9.6	0.7
Netherlands	3.4	3.9	4.2	4.4	4.5	4.7	4.9	0.6
Other Western Europe	16.6	20.6	21.1	21.3	22.2	23.2	24.3	0.6
Industrialized Asia	**22.3**	**27.5**	**27.7**	**30.6**	**32.0**	**33.4**	**35.1**	**1.0**
Japan	17.9	21.8	21.9	23.9	24.7	25.4	26.3	0.8
Australia/New Zealand	4.4	5.7	5.8	6.7	7.3	7.9	8.8	1.8
Total Industrialized	**182.8**	**213.0**	**211.5**	**236.3**	**250.4**	**265.1**	**281.4**	**1.2**
EE/FSU								
Former Soviet Union	**60.7**	**40.8**	**41.9**	**46.2**	**50.6**	**55.1**	**59.8**	**1.5**
Russia	39.3	27.4	28.2	31.4	33.8	36.2	38.3	1.3
Other FSU	21.4	13.4	13.7	14.8	16.7	18.9	21.5	1.9
Eastern Europe	**15.6**	**11.3**	**11.4**	**12.8**	**13.8**	**15.2**	**15.8**	**1.4**
Total EE/FSU	**76.3**	**52.2**	**53.3**	**59.0**	**64.3**	**70.3**	**75.6**	**1.5**
Developing Countries								
Developing Asia	**52.5**	**80.5**	**85.0**	**110.6**	**129.7**	**150.5**	**173.4**	**3.0**
China	27.0	37.0	39.7	54.6	65.7	77.7	91.0	3.5
India	7.8	12.7	12.8	16.4	19.5	23.2	27.1	3.2
South Korea	3.8	7.9	8.1	10.1	11.3	12.3	13.3	2.1
Other Asia	13.9	23.0	24.5	29.4	33.3	37.3	42.0	2.3
Middle East	**13.1**	**20.3**	**20.8**	**25.0**	**27.7**	**30.7**	**34.1**	**2.1**
Turkey	2.0	3.0	2.9	3.7	4.2	4.6	5.0	2.3
Other Middle East	11.1	17.3	17.9	21.2	23.6	26.1	29.1	2.0
Africa	**9.3**	**11.9**	**12.4**	**14.6**	**16.7**	**19.0**	**21.5**	**2.3**
Central and South America	**14.4**	**21.0**	**20.9**	**25.4**	**28.4**	**32.2**	**36.9**	**2.4**
Brazil	6.0	9.0	8.8	10.5	12.1	13.8	15.7	2.5
Other Central/South America	8.5	12.0	12.2	14.9	16.3	18.5	21.1	2.3
Total Developing	**89.3**	**133.8**	**139.2**	**175.5**	**202.5**	**232.4**	**265.9**	**2.7**
Total World	**348.4**	**398.9**	**403.9**	**470.8**	**517.3**	**567.8**	**622.9**	**1.8**

[a]Includes the 50 States and the District of Columbia.

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 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table A1; and System for the Analysis of Global Energy Markets (2004).

Table A2. World Total Energy Consumption by Region and Fuel, Reference Case, 1990-2025
(Quadrillion Btu)

Region/Country	History			Projections				Average Annual Percent Change, 2001-2025
	1990	2000	2001	2010	2015	2020	2025	
Industrialized Countries								
North America								
Oil	40.4	46.3	45.9	53.3	58.3	62.1	67.3	1.6
Natural Gas	23.1	28.8	27.6	32.6	35.3	38.7	40.9	1.6
Coal	20.7	24.5	23.9	27.4	28.6	30.7	34.2	1.5
Nuclear	6.9	8.7	8.9	9.6	9.8	10.0	9.7	0.4
Other	9.5	10.6	9.4	11.6	12.7	13.5	14.4	1.8
Total	**100.6**	**118.7**	**115.6**	**134.5**	**144.6**	**155.0**	**166.6**	**1.5**
Western Europe								
Oil	25.8	28.5	28.9	30.4	31.2	32.0	32.5	0.5
Natural Gas	9.7	14.9	15.1	16.8	18.6	21.0	24.3	2.0
Coal	12.4	8.4	8.6	7.7	7.4	7.1	7.0	-0.9
Nuclear	7.4	8.8	9.1	9.5	9.4	8.9	7.9	-0.6
Other	4.5	6.0	6.1	6.8	7.2	7.6	8.0	1.1
Total	**59.9**	**66.8**	**68.2**	**71.2**	**73.8**	**76.7**	**79.7**	**0.7**
Industrialized Asia								
Oil	12.1	13.2	13.0	14.0	14.3	14.5	15.1	0.6
Natural Gas	2.5	4.0	4.1	4.6	5.1	5.6	6.3	1.8
Coal	4.2	5.7	5.9	6.4	6.7	7.0	7.5	1.0
Nuclear	2.0	3.0	3.2	3.8	4.0	4.4	4.2	1.2
Other	1.6	1.6	1.6	1.8	1.9	1.9	2.0	0.9
Total	**22.3**	**27.5**	**27.7**	**30.6**	**32.0**	**33.4**	**35.1**	**1.0**
Total Industrialized								
Oil	78.2	88.1	87.8	97.8	103.8	108.6	114.9	1.1
Natural Gas	35.4	47.7	46.8	54.0	59.0	65.4	71.4	1.8
Coal	37.3	38.6	38.5	41.4	42.7	44.8	48.7	1.0
Nuclear	16.3	20.5	21.2	22.9	23.2	23.3	21.9	0.1
Other	15.6	18.2	17.1	20.2	21.7	23.0	24.4	1.5
Total	**182.8**	**213.0**	**211.5**	**236.3**	**250.4**	**265.1**	**281.4**	**1.2**
EE/FSU								
Oil	21.0	10.9	11.0	12.4	14.0	15.9	17.8	2.0
Natural Gas	28.8	23.3	23.8	27.7	31.3	35.8	39.5	2.1
Coal	20.8	12.2	12.4	11.9	11.6	11.3	11.1	-0.5
Nuclear	2.9	3.0	3.1	3.4	3.5	3.2	2.9	-0.3
Other	2.8	3.0	3.2	3.6	4.0	4.1	4.4	1.3
Total	**76.3**	**52.2**	**53.3**	**59.0**	**64.3**	**70.3**	**75.6**	**1.5**
Developing Countries								
Developing Asia								
Oil	16.1	30.2	30.7	42.0	49.2	57.4	65.7	3.2
Natural Gas	3.2	6.9	7.9	10.1	12.3	15.1	18.7	3.6
Coal	29.1	37.1	39.4	48.2	55.1	62.8	71.9	2.5
Nuclear	0.9	1.7	1.8	3.1	4.2	4.9	5.1	4.4
Other	3.2	4.5	5.1	7.2	8.9	10.3	11.9	3.6
Total	**52.5**	**80.5**	**85.0**	**110.6**	**129.7**	**150.5**	**173.4**	**3.0**

See notes at end of table.

Table A2. World Total Energy Consumption by Region and Fuel, Reference Case, 1990-2025 (Continued)
(Quadrillion Btu)

Region/Country	History 1990	History 2000	History 2001	Projections 2010	Projections 2015	Projections 2020	Projections 2025	Average Annual Percent Change, 2001-2025
Developing Countries (Continued)								
Middle East								
Oil	8.0	11.0	11.1	14.1	15.5	17.2	18.7	2.2
Natural Gas	3.9	7.7	8.2	8.9	9.9	11.0	12.6	1.8
Coal	0.8	1.1	1.1	1.3	1.4	1.5	1.6	1.7
Nuclear	0.0	0.0	0.0	0.1	0.1	0.1	0.2	—
Other	0.4	0.5	0.4	0.6	0.7	0.8	1.0	3.7
Total	**13.1**	**20.3**	**20.8**	**25.0**	**27.7**	**30.7**	**34.1**	**2.1**
Africa								
Oil	4.2	5.2	5.3	6.4	7.3	8.5	9.6	2.5
Natural Gas	1.5	2.2	2.5	2.9	3.5	4.2	5.0	3.0
Coal	3.0	3.7	3.8	4.1	4.6	5.0	5.4	1.4
Nuclear	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1.2
Other	0.6	0.7	0.8	1.0	1.1	1.2	1.5	2.7
Total	**9.3**	**11.9**	**12.4**	**14.6**	**16.7**	**19.0**	**21.5**	**2.3**
Central and South America								
Oil	7.7	10.6	10.5	12.7	14.2	16.3	18.7	2.4
Natural Gas	2.2	3.6	3.8	4.9	6.0	7.4	9.2	3.8
Coal	0.6	0.9	0.8	1.1	1.2	1.4	1.5	2.7
Nuclear	0.1	0.1	0.2	0.2	0.2	0.2	0.2	-0.7
Other	3.9	5.9	5.6	6.4	6.7	7.0	7.3	1.2
Total	**14.4**	**21.0**	**20.9**	**25.4**	**28.4**	**32.2**	**36.9**	**2.4**
Total Developing Countries								
Oil	35.9	56.9	57.6	75.2	86.3	99.3	112.6	2.8
Natural Gas	10.8	20.4	22.4	26.8	31.7	37.6	45.5	3.0
Coal	33.5	42.8	45.1	54.7	62.3	70.7	80.4	2.4
Nuclear	1.1	2.0	2.2	3.5	4.7	5.4	5.7	4.1
Other	8.0	11.6	11.8	15.2	17.5	19.5	21.7	2.5
Total	**89.3**	**133.8**	**139.2**	**175.5**	**202.5**	**232.4**	**265.9**	**2.7**
Total World								
Oil	135.1	155.9	156.5	185.4	204.0	223.8	245.3	1.9
Natural Gas	75.0	91.4	93.1	108.5	122.0	138.8	156.5	2.2
Coal	91.6	93.6	95.9	108.0	116.6	126.8	140.2	1.6
Nuclear	20.3	25.5	26.4	29.8	31.4	31.8	30.4	0.6
Other	26.4	32.8	32.2	39.0	43.2	46.6	50.4	1.9
Total	**348.4**	**398.9**	**403.9**	**470.8**	**517.3**	**567.8**	**622.9**	**1.8**

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 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table A1; and System for the Analysis of Global Energy Markets (2004).

Table A3. World Gross Domestic Product (GDP) by Region, Reference Case, 1990-2025
(Billion 1997 Dollars)

Region/Country	History 1990	History 2000	History 2001	Projections 2010	Projections 2015	Projections 2020	Projections 2025	Average Annual Percent Change, 2001-2025
Industrialized Countries								
North America	**7,723**	**10,573**	**10,609**	**14,014**	**16,228**	**18,675**	**21,461**	**3.0**
United States[a]	6,839	9,370	9,394	12,427	14,376	16,503	18,881	3.0
Canada	553	737	751	981	1,121	1,269	1,427	2.7
Mexico	331	465	464	606	731	903	1,153	3.9
Western Europe	**7,635**	**9,356**	**9,513**	**11,233**	**12,495**	**13,894**	**15,423**	**2.0**
United Kingdom	1,153	1,461	1,492	1,846	2,093	2,360	2,655	2.4
France	1,300	1,568	1,601	1,888	2,102	2,348	2,629	2.1
Germany	1,917	2,261	2,284	2,582	2,809	3,055	3,313	1.6
Italy	1,063	1,248	1,269	1,470	1,620	1,791	1,971	1.9
Netherlands	317	423	428	490	543	604	674	1.9
Other Western Europe	1,885	2,396	2,440	2,957	3,328	3,736	4,181	2.3
Industrialized Asia	**4,189**	**4,925**	**4,955**	**5,800**	**6,388**	**7,004**	**7,661**	**1.8**
Japan	3,808	4,395	4,411	5,085	5,557	6,046	6,563	1.7
Australia/New Zealand	381	530	543	715	831	958	1,098	3.0
Total Industrialized	**19,546**	**24,854**	**25,077**	**31,047**	**35,111**	**39,574**	**44,545**	**2.4**
EE/FSU								
Former Soviet Union	**929**	**597**	**632**	**970**	**1,196**	**1,443**	**1,710**	**4.2**
Russia	668	449	471	695	840	999	1,165	3.8
Other FSU	261	148	161	276	355	444	545	5.2
Eastern Europe	**353**	**379**	**389**	**550**	**667**	**810**	**971**	**3.9**
Total EE/FSU	**1,282**	**976**	**1,022**	**1,521**	**1,863**	**2,253**	**2,680**	**4.1**
Developing Countries								
Developing Asia	**1,766**	**3,403**	**3,536**	**5,854**	**7,540**	**9,464**	**11,714**	**5.1**
China	428	1,120	1,202	2,228	2,980	3,877	4,976	6.1
India	290	492	520	833	1,078	1,381	1,757	5.2
South Korea	299	544	562	908	1,117	1,310	1,510	4.2
Other Asia	749	1,246	1,253	1,885	2,366	2,896	3,471	4.3
Middle East	**409**	**594**	**584**	**821**	**987**	**1,176**	**1,389**	**3.7**
Turkey	139	198	183	278	340	412	492	4.2
Other Middle East	270	396	400	542	646	764	897	3.4
Africa	**488**	**606**	**626**	**903**	**1,101**	**1,332**	**1,596**	**4.0**
Central and South America	**1,105**	**1,503**	**1,510**	**1,968**	**2,419**	**2,967**	**3,650**	**3.7**
Brazil	655	851	863	1,132	1,390	1,697	2,076	3.7
Other Central/South America	450	652	647	836	1,029	1,269	1,574	3.8
Total Developing	**3,767**	**6,106**	**6,256**	**9,545**	**12,047**	**14,939**	**18,349**	**4.6**
Total World	**24,596**	**31,937**	**32,354**	**42,113**	**49,020**	**56,765**	**65,574**	**3.0**

[a]Includes the 50 States and the District of Columbia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding.

Sources: Global Insight, Inc., *World Economic Outlook*, Vol. 1 (Lexington, MA, Third Quarter 2003), and Energy Information Administration, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table A20.

Table A4. World Oil Consumption by Region, Reference Case, 1990-2025
(Million Barrels per Day)

Region/Country	History 1990	History 2000	History 2001	Projections 2010	Projections 2015	Projections 2020	Projections 2025	Average Annual Percent Change, 2001-2025
Industrialized Countries								
North America	**20.4**	**23.8**	**23.5**	**27.4**	**29.9**	**31.9**	**34.6**	**1.6**
United States[a]	17.0	19.7	19.6	22.7	24.8	26.4	28.3	1.5
Canada	1.7	2.1	1.9	2.3	2.5	2.6	2.8	1.6
Mexico	1.7	2.0	1.9	2.4	2.6	2.9	3.5	2.5
Western Europe	**12.5**	**13.8**	**14.0**	**14.7**	**15.1**	**15.4**	**15.7**	**0.5**
United Kingdom	1.8	1.7	1.7	1.9	1.9	2.0	2.2	1.0
France	1.8	2.0	2.0	2.1	2.1	2.1	2.2	0.2
Germany	2.7	2.8	2.8	3.0	3.1	3.2	3.3	0.6
Italy	1.9	1.9	1.9	2.0	2.1	2.1	2.2	0.6
Netherlands	0.7	0.9	0.9	0.9	0.9	0.9	1.0	0.3
Other Western Europe	3.6	4.6	4.7	4.9	5.0	5.0	5.0	0.3
Industrialized Asia	**6.0**	**6.5**	**6.4**	**7.0**	**7.1**	**7.2**	**7.5**	**0.7**
Japan	5.1	5.5	5.4	5.7	5.7	5.7	5.8	0.3
Australia/New Zealand	0.8	1.0	1.0	1.3	1.4	1.5	1.7	2.2
Total Industrialized	**38.8**	**44.1**	**43.9**	**49.1**	**52.1**	**54.6**	**57.8**	**1.2**
EE/FSU								
Former Soviet Union	**8.4**	**3.8**	**3.9**	**4.4**	**5.0**	**5.7**	**6.4**	**2.1**
Russia	5.4	2.6	2.6	2.9	3.3	3.8	4.3	2.1
Other FSU	3.0	1.2	1.3	1.5	1.7	1.9	2.2	2.1
Eastern Europe	**1.6**	**1.4**	**1.4**	**1.6**	**1.7**	**1.9**	**2.1**	**1.7**
Total EE/FSU	**10.0**	**5.2**	**5.3**	**5.9**	**6.7**	**7.6**	**8.5**	**2.0**
Developing Countries								
Developing Asia	**7.6**	**14.5**	**14.8**	**20.2**	**23.7**	**27.6**	**31.6**	**3.2**
China	2.3	4.8	5.0	7.6	9.2	11.0	12.8	4.0
India	1.2	2.1	2.1	2.8	3.5	4.4	5.3	3.9
South Korea	1.0	2.1	2.1	2.5	2.6	2.7	2.9	1.3
Other Asia	3.1	5.5	5.5	7.3	8.4	9.5	10.7	2.8
Middle East	**3.8**	**5.3**	**5.4**	**6.8**	**7.5**	**8.3**	**9.1**	**2.2**
Turkey	0.5	0.7	0.6	0.8	0.9	1.0	1.1	2.4
Other Middle East	3.4	4.7	4.7	6.0	6.6	7.3	8.0	2.2
Africa	**2.1**	**2.5**	**2.6**	**3.1**	**3.6**	**4.1**	**4.7**	**2.5**
Central and South America	**3.7**	**5.2**	**5.2**	**6.3**	**7.0**	**8.0**	**9.2**	**2.4**
Brazil	1.5	2.2	2.2	2.6	2.9	3.3	3.8	2.3
Other Central/South America	2.3	3.0	3.0	3.7	4.1	4.7	5.4	2.5
Total Developing	**17.3**	**27.6**	**27.9**	**36.4**	**41.8**	**48.1**	**54.5**	**2.8**
Total World	**66.1**	**76.9**	**77.1**	**91.4**	**100.5**	**110.3**	**120.9**	**1.9**

[a]Includes the 50 States and the District of Columbia.

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 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table A21; and System for the Analysis of Global Energy Markets (2004).

Table A5. World Natural Gas Consumption by Region, Reference Case, 1990-2025
(Trillion Cubic Feet)

Region/Country	History 1990	History 2000	History 2001	Projections 2010	Projections 2015	Projections 2020	Projections 2025	Average Annual Percent Change, 2001-2025
Industrialized Countries								
North America	**22.5**	**28.1**	**26.9**	**31.8**	**34.4**	**37.7**	**39.8**	**1.6**
United States[a]	19.2	23.5	22.6	26.2	28.0	30.4	31.4	1.4
Canada	2.4	3.3	2.9	3.9	4.3	4.6	4.9	2.2
Mexico	0.9	1.4	1.4	1.7	2.1	2.7	3.5	3.9
Western Europe	**10.1**	**14.6**	**14.8**	**16.4**	**18.2**	**20.6**	**23.7**	**2.0**
United Kingdom	2.1	3.4	3.3	3.8	4.3	4.8	5.2	2.0
France	1.0	1.4	1.5	1.5	1.6	1.7	1.8	0.8
Germany	2.7	3.2	3.3	3.6	4.1	5.2	5.6	2.2
Italy	1.7	2.5	2.5	2.8	3.1	3.4	3.5	1.4
Netherlands	1.5	1.7	1.8	1.8	2.0	2.1	2.2	1.0
Other Western Europe	1.2	2.3	2.4	2.9	3.1	3.4	5.3	3.3
Industrialized Asia	**2.6**	**3.8**	**3.9**	**4.4**	**4.9**	**5.3**	**6.0**	**1.8**
Japan	1.9	2.8	2.8	3.2	3.5	3.8	4.2	1.6
Australia/New Zealand	0.8	1.0	1.1	1.2	1.3	1.5	1.8	2.2
Total Industrialized	**35.2**	**46.4**	**45.6**	**52.6**	**57.4**	**63.6**	**69.5**	**1.8**
EE/FSU								
Former Soviet Union	**25.0**	**20.5**	**20.8**	**23.4**	**26.2**	**29.5**	**32.8**	**1.9**
Russia	17.3	14.1	14.4	15.8	17.5	19.5	21.2	1.6
Other FSU	7.7	6.4	6.4	7.6	8.6	10.0	11.6	2.5
Eastern Europe	**3.1**	**2.4**	**2.7**	**3.9**	**4.7**	**5.9**	**6.1**	**3.6**
Total EE/FSU	**28.1**	**23.0**	**23.5**	**27.3**	**30.9**	**35.3**	**39.0**	**2.1**
Developing Countries								
Developing Asia	**3.0**	**6.6**	**7.5**	**9.5**	**11.6**	**14.1**	**17.4**	**3.5**
China	0.5	1.0	1.0	1.9	2.6	3.6	5.0	6.9
India	0.4	0.8	0.8	1.2	1.6	2.0	2.5	4.8
South Korea	0.1	0.7	0.7	1.0	1.3	1.5	1.8	3.9
Other Asia	2.0	4.2	4.9	5.4	6.1	7.0	8.1	2.1
Middle East	**3.7**	**7.3**	**7.9**	**8.5**	**9.5**	**10.5**	**12.1**	**1.8**
Turkey	0.1	0.5	0.6	0.8	0.9	1.0	1.1	2.9
Other Middle East	3.6	6.8	7.3	7.7	8.6	9.5	10.9	1.7
Africa	**1.4**	**2.0**	**2.3**	**2.7**	**3.3**	**3.9**	**4.6**	**3.0**
Central and South America	**2.0**	**3.3**	**3.5**	**4.5**	**5.5**	**6.8**	**8.5**	**3.8**
Brazil	0.1	0.3	0.3	0.9	1.6	2.0	2.6	8.8
Other Central/South America	1.9	3.0	3.2	3.6	3.9	4.8	5.9	2.6
Total Developing	**10.1**	**19.3**	**21.2**	**25.2**	**29.8**	**35.3**	**42.6**	**2.9**
Total World	**73.4**	**88.7**	**90.3**	**105.1**	**118.1**	**134.2**	**151.1**	**2.2**

[a]Includes the 50 States and the District of Columbia.

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 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table A13; and System for the Analysis of Global Energy Markets (2004).

Table A6. World Coal Consumption by Region, Reference Case, 1990-2025
(Million Short Tons)

Region/Country	History			Projections				Average Annual Percent Change, 2001-2025
	1990	2000	2001	2010	2015	2020	2025	
Industrialized Countries								
North America	**971**	**1,168**	**1,148**	**1,325**	**1,394**	**1,498**	**1,680**	**1.6**
United States[a]	903	1,084	1,060	1,229	1,291	1,391	1,567	1.6
Canada	59	69	73	77	81	83	87	0.8
Mexico	9	15	15	19	22	24	26	2.4
Western Europe	**894**	**559**	**574**	**513**	**493**	**474**	**463**	**-0.9**
United Kingdom	119	64	71	65	63	56	49	-1.5
France	35	25	21	13	12	12	11	-2.7
Germany	528	264	265	258	242	234	232	-0.5
Italy	25	20	22	21	21	20	20	-0.5
Netherlands	15	14	23	17	16	16	16	-1.7
Other Western Europe	172	172	172	140	140	136	135	-1.0
Industrialized Asia	**231**	**303**	**312**	**336**	**355**	**373**	**404**	**1.1**
Japan	125	160	166	178	186	195	202	0.8
Australia/New Zealand	106	143	147	158	169	179	201	1.3
Total Industrialized	**2,095**	**2,029**	**2,034**	**2,174**	**2,242**	**2,345**	**2,547**	**0.9**
EE/FSU								
Former Soviet Union	**848**	**421**	**446**	**441**	**442**	**441**	**436**	**-0.1**
Russia	497	267	284	298	304	302	297	0.2
Other FSU	352	154	162	143	138	138	138	-0.7
Eastern Europe	**528**	**390**	**382**	**348**	**321**	**297**	**289**	**-1.2**
Total EE/FSU	**1,376**	**811**	**828**	**788**	**763**	**738**	**724**	**-0.6**
Developing Countries								
Developing Asia	**1,590**	**1,959**	**2,084**	**2,553**	**2,928**	**3,343**	**3,834**	**2.6**
China	1,124	1,282	1,383	1,740	2,041	2,371	2,757	2.9
India	242	359	360	430	484	543	611	2.2
South Korea	49	72	76	104	115	119	127	2.2
Other Asia	175	246	265	280	288	310	339	1.0
Middle East	**66**	**94**	**95**	**116**	**125**	**134**	**142**	**1.7**
Turkey	60	80	81	96	107	114	122	1.7
Other Middle East	6	14	14	19	19	20	20	1.6
Africa	**152**	**187**	**191**	**206**	**228**	**249**	**268**	**1.4**
Central and South America	**27**	**34**	**32**	**43**	**48**	**54**	**59**	**2.7**
Brazil	17	21	21	30	32	36	39	2.7
Other Central/South America	10	13	11	14	16	18	20	2.6
Total Developing	**1,835**	**2,275**	**2,401**	**2,918**	**3,330**	**3,780**	**4,303**	**2.5**
Total World	**5,307**	**5,115**	**5,263**	**5,881**	**6,335**	**6,862**	**7,574**	**1.5**

[a]Includes the 50 States and the District of Columbia.

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 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table A16; and System for the Analysis of Global Energy Markets (2004).

Table A7. World Nuclear Energy Consumption by Region, Reference Case, 1990-2025
(Billion Kilowatthours)

Region/Country	History			Projections				Average Annual Percent Change, 2001-2025
	1990	2000	2001	2010	2015	2020	2025	
Industrialized Countries								
North America	**649**	**830**	**850**	**912**	**932**	**945**	**925**	**0.4**
United States[a]	577	754	769	794	812	816	816	0.3
Canada	69	69	73	108	110	118	98	1.2
Mexico	3	8	8	10	10	11	11	1.1
Western Europe	**703**	**845**	**870**	**906**	**897**	**855**	**760**	**-0.6**
United Kingdom	59	82	86	69	52	47	28	-4.6
France	298	394	401	447	478	520	550	1.3
Germany	145	161	163	137	107	15	0	-100.0
Italy	0	0	0	0	0	0	0	—
Netherlands	3	4	4	4	4	0	0	-100.0
Other Western Europe	198	204	217	248	257	273	182	-0.7
Industrialized Asia	**192**	**294**	**309**	**369**	**394**	**426**	**411**	**1.2**
Japan	192	294	309	369	394	426	411	1.2
Australia/New Zealand	0	0	0	0	0	0	0	—
Total Industrialized	**1,544**	**1,969**	**2,029**	**2,187**	**2,223**	**2,226**	**2,095**	**0.1**
EE/FSU								
Former Soviet Union	**201**	**204**	**210**	**236**	**236**	**204**	**174**	**-0.8**
Russia	115	122	125	141	154	129	99	-1.0
Other FSU	86	81	85	95	82	76	75	-0.5
Eastern Europe	**54**	**67**	**72**	**76**	**80**	**84**	**88**	**0.8**
Total EE/FSU	**256**	**270**	**282**	**312**	**316**	**288**	**262**	**-0.3**
Developing Countries								
Developing Asia	**88**	**171**	**178**	**299**	**406**	**473**	**497**	**4.4**
China	0	16	17	66	129	142	154	9.7
India	6	14	18	46	55	66	66	5.5
South Korea	50	104	107	141	171	209	220	3.1
Other Asia	32	37	36	47	51	55	56	1.8
Middle East	**0**	**0**	**0**	**5**	**14**	**14**	**21**	**—**
Turkey	0	0	0	0	0	0	0	—
Other Middle East	0	0	0	5	14	14	21	—
Africa	**8**	**13**	**11**	**14**	**14**	**14**	**14**	**1.2**
Central and South America	**9**	**11**	**21**	**21**	**21**	**18**	**18**	**-0.7**
Brazil	2	5	14	14	14	14	14	0.0
Other Central/South America	7	6	7	6	6	3	3	-2.8
Total Developing	**105**	**195**	**209**	**339**	**455**	**518**	**549**	**4.1**
Total World	**1,905**	**2,434**	**2,521**	**2,838**	**2,994**	**3,032**	**2,906**	**0.6**

[a]Includes the 50 States and the District of Columbia.

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 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table A8; and System for the Analysis of Global Energy Markets (2004).

Table A8. World Consumption of Hydroelectricity and Other Renewable Energy by Region, Reference Case, 1990-2025
(Quadrillion Btu)

Region/Country	History			Projections				Average Annual Percent Change, 2001-2025
	1990	2000	2001	2010	2015	2020	2025	
Industrialized Countries								
North America	**9.5**	**10.6**	**9.4**	**11.6**	**12.7**	**13.5**	**14.4**	**1.8**
United States[a]	6.0	6.4	5.5	7.3	7.9	8.5	9.0	2.1
Canada	3.1	3.8	3.5	3.8	4.2	4.4	4.7	1.3
Mexico	0.3	0.5	0.4	0.5	0.5	0.6	0.6	1.7
Western Europe	**4.5**	**6.0**	**6.1**	**6.8**	**7.2**	**7.6**	**8.0**	**1.1**
United Kingdom	0.1	0.1	0.1	0.2	0.2	0.2	0.3	5.5
France	0.6	0.7	0.8	0.9	0.9	1.0	1.0	0.8
Germany	0.3	0.4	0.5	0.5	0.6	0.6	0.6	1.3
Italy	0.4	0.6	0.6	0.8	0.9	0.9	0.9	1.7
Netherlands	0.0	0.1	0.1	0.2	0.2	0.2	0.2	6.2
Other Western Europe	3.2	4.1	4.1	4.1	4.5	4.8	4.9	0.8
Industrialized Asia	**1.6**	**1.6**	**1.6**	**1.8**	**1.9**	**1.9**	**2.0**	**0.9**
Japan	1.1	1.1	1.1	1.3	1.3	1.3	1.4	0.9
Australia/New Zealand	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.7
Total Industrialized	**15.6**	**18.2**	**17.1**	**20.2**	**21.7**	**23.0**	**24.4**	**1.5**
EE/FSU								
Former Soviet Union	**2.4**	**2.3**	**2.5**	**2.9**	**3.1**	**3.2**	**3.4**	**1.2**
Russia	1.8	1.7	1.8	2.0	2.1	2.2	2.3	1.0
Other FSU	0.6	0.7	0.7	0.9	1.0	1.0	1.0	1.7
Eastern Europe	**0.4**	**0.6**	**0.6**	**0.7**	**0.9**	**1.0**	**1.0**	**1.8**
Total EE/FSU	**2.8**	**3.0**	**3.2**	**3.6**	**4.0**	**4.1**	**4.4**	**1.3**
Developing Countries								
Developing Asia	**3.2**	**4.5**	**5.1**	**7.2**	**8.9**	**10.3**	**11.9**	**3.6**
China	1.3	2.3	2.8	4.2	5.0	5.9	6.8	3.8
India	0.7	0.8	0.8	1.1	1.3	1.5	1.8	3.2
South Korea	0.0	0.0	0.0	0.1	0.1	0.1	0.1	5.9
Other Asia	1.1	1.4	1.5	1.9	2.5	2.9	3.2	3.3
Middle East	**0.4**	**0.5**	**0.4**	**0.6**	**0.7**	**0.8**	**1.0**	**3.7**
Turkey	0.2	0.3	0.3	0.4	0.4	0.5	0.6	3.4
Other Middle East	0.1	0.1	0.1	0.2	0.3	0.3	0.4	4.1
Africa	**0.6**	**0.7**	**0.8**	**1.0**	**1.1**	**1.2**	**1.5**	**2.7**
Central and South America	**3.9**	**5.9**	**5.6**	**6.4**	**6.7**	**7.0**	**7.3**	**1.2**
Brazil	2.2	3.3	2.9	3.4	3.6	3.9	4.1	1.5
Other Central/South America	1.7	2.6	2.7	3.1	3.2	3.2	3.2	0.8
Total Developing	**8.0**	**11.6**	**11.8**	**15.2**	**17.5**	**19.5**	**21.7**	**2.5**
Total World	**26.4**	**32.8**	**32.2**	**39.0**	**43.2**	**46.6**	**50.4**	**1.9**

[a]Includes the 50 States and the District of Columbia.

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 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table A1; and System for the Analysis of Global Energy Markets (2004).

Table A9. World Carbon Dioxide Emissions by Region, Reference Case, 1990-2025
(Million Metric Tons Carbon Dioxide)

Region/Country	History			Projections				Average Annual Percent Change, 2001-2025
	1990	2000	2001	2010	2015	2020	2025	
Industrialized Countries								
North America	**5,769**	**6,731**	**6,613**	**7,677**	**8,255**	**8,876**	**9,659**	**1.6**
United States[a]	4,989	5,787	5,692	6,559	7,028	7,536	8,142	1.5
Canada	473	581	569	686	734	776	830	1.6
Mexico	308	364	352	433	492	565	687	2.8
Western Europe	**3,412**	**3,442**	**3,465**	**3,567**	**3,682**	**3,832**	**4,022**	**0.6**
United Kingdom	600	553	563	608	642	665	692	0.9
France	374	401	396	390	398	400	412	0.2
Germany	995	828	819	851	874	943	969	0.7
Italy	415	443	445	486	504	522	540	0.8
Netherlands	211	228	248	263	272	279	286	0.6
Other Western Europe	816	989	994	969	992	1,021	1,123	0.5
Industrialized Asia	**1,280**	**1,526**	**1,556**	**1,694**	**1,770**	**1,840**	**1,962**	**1.0**
Japan	987	1,138	1,158	1,239	1,274	1,300	1,356	0.7
Australia/New Zealand	294	387	398	455	497	541	605	1.8
Total Industrialized	**10,462**	**11,699**	**11,634**	**12,938**	**13,708**	**14,548**	**15,643**	**1.2**
EE/FSU								
Former Soviet Union	**3,798**	**2,338**	**2,399**	**2,600**	**2,840**	**3,118**	**3,393**	**1.5**
Russia	2,405	1,570	1,614	1,792	1,913	2,059	2,186	1.3
Other FSU	1,393	767	785	808	927	1,059	1,207	1.8
Eastern Europe	**1,104**	**756**	**748**	**797**	**827**	**888**	**920**	**0.9**
Total EE/FSU	**4,902**	**3,094**	**3,148**	**3,397**	**3,667**	**4,006**	**4,313**	**1.3**
Developing Countries								
Developing Asia	**3,994**	**5,709**	**6,012**	**7,647**	**8,863**	**10,240**	**11,801**	**2.9**
China	2,262	2,861	3,050	4,063	4,824	5,693	6,666	3.3
India	561	914	917	1,141	1,341	1,575	1,834	2.9
South Korea	234	425	443	563	620	662	720	2.0
Other Asia	937	1,509	1,602	1,881	2,078	2,310	2,581	2.0
Middle East	**846**	**1,262**	**1,299**	**1,566**	**1,729**	**1,910**	**2,110**	**2.0**
Turkey	129	184	184	249	280	309	340	2.6
Other Middle East	717	1,078	1,115	1,317	1,448	1,601	1,770	1.9
Africa	**656**	**811**	**843**	**971**	**1,110**	**1,259**	**1,413**	**2.2**
Central and South America	**703**	**961**	**964**	**1,194**	**1,358**	**1,578**	**1,845**	**2.7**
Brazil	250	343	347	451	531	617	720	3.1
Other Central/South America	453	618	617	744	827	961	1,125	2.5
Total Developing	**6,200**	**8,744**	**9,118**	**11,379**	**13,060**	**14,987**	**17,168**	**2.7**
Total World	**21,563**	**23,536**	**23,899**	**27,715**	**30,435**	**33,541**	**37,124**	**1.9**

[a]Includes the 50 States and the District of Columbia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. The U.S. numbers include carbon dioxide emissions attributable to renewable energy sources.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table A19; and System for the Analysis of Global Energy Markets (2004).

Table A10. World Carbon Dioxide Emissions from Oil Use by Region, Reference Case, 1990-2025
(Million Metric Tons Carbon Dioxide)

Region/Country	History			Projections				Average Annual Percent Change, 2001-2025
	1990	2000	2001	2010	2015	2020	2025	
Industrialized Countries								
North America	**2,626**	**2,935**	**2,962**	**3,403**	**3,723**	**3,968**	**4,300**	**1.6**
United States[a]	2,165	2,416	2,458	2,786	3,051	3,241	3,473	1.5
Canada	222	258	258	311	332	354	378	1.6
Mexico	239	261	251	306	340	373	449	2.5
Western Europe	**1,739**	**1,853**	**1,845**	**1,943**	**1,990**	**2,038**	**2,073**	**0.5**
United Kingdom	242	231	231	251	259	272	293	1.0
France	245	267	267	275	278	279	284	0.2
Germany	376	357	348	366	379	399	404	0.6
Italy	270	261	261	284	289	293	302	0.6
Netherlands	99	98	98	99	102	103	106	0.3
Other Western Europe	507	639	639	667	683	691	684	0.3
Industrialized Asia	**768**	**802**	**802**	**870**	**889**	**905**	**942**	**0.7**
Japan	655	667	668	702	704	700	718	0.3
Australia/New Zealand	113	134	134	169	186	205	225	2.2
Total Industrialized	**5,133**	**5,589**	**5,613**	**6,215**	**6,602**	**6,910**	**7,315**	**1.1**
EE/FSU								
Former Soviet Union	**1,224**	**547**	**557**	**628**	**718**	**821**	**922**	**2.1**
Russia	783	366	369	416	435	480	523	1.5
Other FSU	441	181	189	211	283	341	399	3.2
Eastern Europe	**243**	**189**	**189**	**209**	**226**	**254**	**281**	**1.7**
Total EE/FSU	**1,468**	**736**	**746**	**837**	**944**	**1,074**	**1,203**	**2.0**
Developing Countries								
Developing Asia	**1,116**	**1,912**	**1,953**	**2,665**	**3,124**	**3,644**	**4,174**	**3.2**
China	345	619	642	985	1,187	1,427	1,650	4.0
India	165	279	279	365	456	572	693	3.9
South Korea	138	239	245	287	302	314	335	1.3
Other Asia	468	775	787	1,028	1,178	1,331	1,496	2.7
Middle East	**568**	**753**	**764**	**973**	**1,071**	**1,187**	**1,292**	**2.2**
Turkey	64	81	81	102	113	123	135	2.1
Other Middle East	504	672	682	871	959	1,065	1,158	2.2
Africa	**304**	**356**	**366**	**443**	**507**	**586**	**660**	**2.5**
Central and South America	**533**	**694**	**691**	**834**	**933**	**1,065**	**1,222**	**2.4**
Brazil	210	276	280	332	371	425	487	2.3
Other Central/South America	323	418	411	503	562	640	735	2.5
Total Developing	**2,521**	**3,716**	**3,774**	**4,916**	**5,635**	**6,482**	**7,349**	**2.8**
Total World	**9,121**	**10,041**	**10,134**	**11,969**	**13,181**	**14,466**	**15,867**	**1.9**

[a]Includes the 50 States and the District of Columbia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table A19; and System for the Analysis of Global Energy Markets (2004).

Table A11. World Carbon Dioxide Emissions from Natural Gas Use by Region, Reference Case, 1990-2025
(Million Metric Tons Carbon Dioxide)

Region/Country	History			Projections				Average Annual Percent Change, 2001-2025
	1990	2000	2001	2010	2015	2020	2025	
Industrialized Countries								
North America	**1,207**	**1,503**	**1,421**	**1,715**	**1,856**	**2,038**	**2,152**	**1.7**
United States[a]	1,025	1,249	1,189	1,409	1,510	1,640	1,692	1.5
Canada	127	177	156	211	230	245	266	2.2
Mexico	54	77	77	95	116	152	194	3.9
Western Europe	**514**	**786**	**799**	**885**	**981**	**1,111**	**1,281**	**2.0**
United Kingdom	110	188	183	204	236	261	284	1.8
France	57	81	85	93	99	100	108	1.0
Germany	116	165	173	194	222	280	303	2.4
Italy	91	135	136	152	166	182	192	1.4
Netherlands	72	81	83	85	94	102	107	1.1
Other Western Europe	67	134	139	156	165	185	287	3.1
Industrialized Asia	**133**	**209**	**216**	**244**	**270**	**295**	**331**	**1.8**
Japan	89	152	157	179	195	209	231	1.6
Australia/New Zealand	44	57	59	65	75	86	99	2.2
Total Industrialized	**1,853**	**2,497**	**2,436**	**2,844**	**3,107**	**3,443**	**3,763**	**1.8**
EE/FSU								
Former Soviet Union	**1,352**	**1,103**	**1,119**	**1,258**	**1,405**	**1,583**	**1,765**	**1.9**
Russia	928	753	768	842	934	1,037	1,131	1.6
Other FSU	424	351	351	416	471	545	634	2.5
Eastern Europe	**167**	**127**	**139**	**205**	**248**	**308**	**322**	**3.6**
Total EE/FSU	**1,519**	**1,231**	**1,258**	**1,463**	**1,653**	**1,890**	**2,087**	**2.1**
Developing Countries								
Developing Asia	**167**	**366**	**419**	**534**	**650**	**796**	**986**	**3.6**
China	31	59	66	131	181	251	346	7.2
India	24	43	44	67	86	107	134	4.8
South Korea	6	40	44	64	83	105	126	4.5
Other Asia	106	225	266	271	300	334	379	1.5
Middle East	**205**	**406**	**435**	**470**	**524**	**580**	**667**	**1.8**
Turkey	7	29	31	61	73	84	96	4.8
Other Middle East	199	377	404	409	452	496	570	1.5
Africa	**80**	**116**	**130**	**153**	**187**	**221**	**264**	**3.0**
Central and South America	**116**	**188**	**200**	**260**	**315**	**389**	**486**	**3.8**
Brazil	6	18	19	53	88	113	144	8.9
Other Central/South America	110	170	182	207	227	276	342	2.7
Total Developing	**569**	**1,077**	**1,184**	**1,416**	**1,676**	**1,986**	**2,402**	**3.0**
Total World	**3,941**	**4,805**	**4,878**	**5,724**	**6,436**	**7,320**	**8,253**	**2.2**

[a]Includes the 50 States and the District of Columbia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table A19; and System for the Analysis of Global Energy Markets (2004).

Table A12. World Carbon Dioxide Emissions from Coal Use by Region, Reference Case, 1990-2025
(Million Metric Tons Carbon Dioxide)

Region/Country	History			Projections				Average Annual Percent Change, 2001-2025
	1990	2000	2001	2010	2015	2020	2025	
Industrialized Countries								
North America	**1,933**	**2,293**	**2,222**	**2,560**	**2,676**	**2,871**	**3,207**	**1.5**
United States[a]	1,794	2,122	2,042	2,364	2,468	2,654	2,977	1.6
Canada	123	146	155	164	172	177	186	0.8
Mexico	15	25	25	32	36	40	44	2.4
Western Europe	**1,159**	**804**	**821**	**740**	**711**	**683**	**669**	**-0.9**
United Kingdom	248	134	149	153	148	132	115	-1.1
France	72	52	44	22	21	21	19	-3.4
Germany	503	306	298	291	273	264	262	-0.5
Italy	54	48	49	49	49	47	47	-0.2
Netherlands	40	49	67	80	76	74	73	0.4
Other Western Europe	242	216	215	145	144	145	152	-1.4
Industrialized Asia	**380**	**515**	**539**	**580**	**611**	**641**	**689**	**1.0**
Japan	243	319	334	359	375	392	407	0.8
Australia/New Zealand	137	196	205	221	236	250	282	1.3
Total Industrialized	**3,472**	**3,613**	**3,581**	**3,879**	**3,998**	**4,195**	**4,564**	**1.0**
EE/FSU								
Former Soviet Union	**1,222**	**687**	**723**	**714**	**717**	**715**	**706**	**-0.1**
Russia	694	452	478	534	544	542	533	0.5
Other FSU	528	236	245	181	173	173	174	-1.4
Eastern Europe	**694**	**440**	**420**	**382**	**353**	**326**	**317**	**-1.2**
Total EE/FSU	**1,915**	**1,127**	**1,143**	**1,097**	**1,070**	**1,041**	**1,024**	**-0.5**
Developing Countries								
Developing Asia	**2,710**	**3,431**	**3,639**	**4,448**	**5,089**	**5,799**	**6,641**	**2.5**
China	1,886	2,183	2,342	2,946	3,456	4,016	4,669	2.9
India	371	592	594	709	798	895	1,007	2.2
South Korea	90	146	155	212	234	243	259	2.2
Other Asia	363	509	549	581	600	645	706	1.1
Middle East	**73**	**103**	**100**	**123**	**133**	**142**	**150**	**1.7**
Turkey	59	74	71	86	95	102	109	1.8
Other Middle East	14	29	29	37	38	40	41	1.5
Africa	**272**	**339**	**347**	**375**	**416**	**453**	**489**	**1.4**
Central and South America	**54**	**78**	**73**	**100**	**110**	**124**	**137**	**2.7**
Brazil	34	49	48	66	72	79	88	2.6
Other Central/South America	20	30	25	34	38	45	49	2.8
Total Developing	**3,110**	**3,951**	**4,160**	**5,046**	**5,749**	**6,519**	**7,417**	**2.4**
Total World	**8,497**	**8,691**	**8,884**	**10,022**	**10,817**	**11,755**	**13,004**	**1.6**

[a]Includes the 50 States and the District of Columbia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table A19; and System for the Analysis of Global Energy Markets (2004).

Table A13. World Total Energy Consumption in Oil-Equivalent Units by Region, Reference Case, 1990-2025
(Million Tons Oil Equivalent)

Region/Country	History			Projections				Average Annual Percent Change, 2001-2025
	1990	2000	2001	2010	2015	2020	2025	
Industrialized Countries								
North America	**2,534**	**2,990**	**2,912**	**3,389**	**3,645**	**3,907**	**4,197**	**1.5**
United States[a]	2,131	2,503	2,446	2,817	3,018	3,224	3,439	1.4
Canada	278	331	315	388	417	441	465	1.6
Mexico	126	156	151	185	210	242	293	2.8
Western Europe	**1,509**	**1,685**	**1,718**	**1,794**	**1,859**	**1,932**	**2,008**	**0.7**
United Kingdom	234	246	247	261	271	283	295	0.7
France	222	261	265	298	310	324	337	1.0
Germany	373	357	362	373	381	391	401	0.4
Italy	177	201	204	214	223	232	241	0.7
Netherlands	85	99	107	110	114	118	122	0.6
Other Western Europe	418	520	533	537	560	584	613	0.6
Industrialized Asia	**563**	**692**	**699**	**771**	**807**	**841**	**885**	**1.0**
Japan	452	548	552	603	623	641	662	0.8
Australia/New Zealand	111	144	147	168	183	200	223	1.8
Total Industrialized	**4,606**	**5,366**	**5,329**	**5,954**	**6,311**	**6,680**	**7,091**	**1.2**
EE/FSU								
Former Soviet Union	**1,529**	**1,029**	**1,055**	**1,163**	**1,274**	**1,388**	**1,507**	**1.5**
Russia	991	690	711	791	852	911	965	1.3
Other FSU	538	339	345	373	422	477	542	1.9
Eastern Europe	**393**	**285**	**287**	**323**	**347**	**383**	**399**	**1.4**
Total EE/FSU	**1,923**	**1,314**	**1,342**	**1,487**	**1,621**	**1,771**	**1,906**	**1.5**
Developing Countries								
Developing Asia	**1,322**	**2,029**	**2,143**	**2,786**	**3,268**	**3,792**	**4,369**	**3.0**
China	681	931	1,000	1,376	1,654	1,958	2,294	3.5
India	196	319	322	413	492	584	682	3.2
South Korea	95	199	203	256	284	309	335	2.1
Other Asia	350	580	617	741	838	941	1,058	2.3
Middle East	**329**	**511**	**524**	**629**	**699**	**774**	**860**	**2.1**
Turkey	50	76	73	94	105	116	127	2.3
Other Middle East	280	435	451	535	594	657	733	2.0
Africa	**235**	**301**	**314**	**367**	**421**	**479**	**542**	**2.3**
Central and South America	**364**	**529**	**527**	**640**	**715**	**812**	**929**	**2.4**
Brazil	150	228	221	265	304	347	396	2.5
Other Central/South America	214	302	306	375	411	465	533	2.3
Total Developing	**2,250**	**3,371**	**3,508**	**4,422**	**5,103**	**5,856**	**6,700**	**2.7**
Total World	**8,779**	**10,052**	**10,179**	**11,863**	**13,036**	**14,308**	**15,697**	**1.8**

[a]Includes the 50 States and the District of Columbia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table A1; and System for the Analysis of Global Energy Markets (2004).

Table A14. World Population by Region, Reference Case, 1990-2025
(Millions)

Region/Country	History 1990	History 2000	History 2001	Projections 2010	Projections 2015	Projections 2020	Projections 2025	Average Annual Percent Change, 2001-2025
Industrialized Countries								
North America	**366**	**405**	**417**	**456**	**476**	**495**	**514**	**0.9**
United States[a]	255	276	286	309	322	335	348	0.8
Canada	28	31	31	33	34	35	36	0.6
Mexico	83	99	100	113	120	125	130	1.1
Western Europe	**376**	**390**	**391**	**396**	**397**	**397**	**397**	**0.1**
United Kingdom	57	59	59	60	61	62	63	0.3
France	57	59	60	62	63	64	64	0.3
Germany	79	82	82	83	82	82	82	0.0
Italy	57	58	57	57	56	54	53	-0.3
Netherlands	15	16	16	17	17	17	17	0.3
Other Western Europe	112	116	117	118	118	118	117	0.0
Industrialized Asia	**144**	**150**	**150**	**153**	**153**	**152**	**151**	**0.0**
Japan	124	127	127	128	127	126	123	-0.1
Australia/New Zealand	20	23	23	25	26	27	28	0.7
Total Industrialized	**886**	**946**	**959**	**1,005**	**1,026**	**1,045**	**1,061**	**0.4**
EE/FSU								
Former Soviet Union	**290**	**290**	**289**	**283**	**280**	**277**	**272**	**-0.2**
Russia	148	146	145	138	133	129	124	-0.6
Other FSU	141	144	144	145	147	148	148	0.1
Eastern Europe	**122**	**121**	**121**	**119**	**118**	**117**	**115**	**-0.2**
Total EE/FSU	**412**	**411**	**410**	**402**	**398**	**393**	**387**	**-0.2**
Developing Countries								
Developing Asia	**2,791**	**3,246**	**3,288**	**3,658**	**3,850**	**4,022**	**4,168**	**1.0**
China	1,155	1,275	1,285	1,365	1,402	1,429	1,445	0.5
India	846	1,017	1,033	1,174	1,246	1,312	1,369	1.2
South Korea	43	47	47	49	50	50	50	0.3
Other Asia	746	907	923	1,071	1,152	1,230	1,304	1.4
Middle East	**193**	**242**	**247**	**294**	**322**	**349**	**375**	**1.8**
Turkey	58	68	69	78	82	86	89	1.0
Other Middle East	136	174	178	216	240	263	286	2.0
Africa	**622**	**796**	**814**	**984**	**1,085**	**1,188**	**1,292**	**1.9**
Central and South America	**358**	**421**	**428**	**481**	**509**	**534**	**557**	**1.1**
Brazil	149	172	174	193	202	210	216	0.9
Other Central/South America	210	250	254	288	307	324	341	1.2
Total Developing	**3,965**	**4,705**	**4,777**	**5,418**	**5,765**	**6,092**	**6,392**	**1.2**
Total World	**5,263**	**6,061**	**6,145**	**6,825**	**7,190**	**7,531**	**7,841**	**1.0**

[a]Includes the 50 States and the District of Columbia.

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 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table A20. **Other Countries:** United Nations, Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, *The 2002 Revision and World Urbanization Prospects* (New York, NY, July 11, 2003).

Appendix B

High Economic Growth Case Projections:

- World Energy Consumption
- Gross Domestic Product
- Carbon Dioxide Emissions

Table B1. World Total Primary Energy Consumption by Region, High Economic Growth Case, 1990-2025
(Quadrillion Btu)

Region/Country	History			Projections				Average Annual Percent Change, 2001-2025
	1990	2000	2001	2010	2015	2020	2025	
Industrialized Countries								
North America	**100.6**	**118.7**	**115.6**	**138.2**	**150.4**	**163.5**	**177.9**	**1.8**
United States[a]	84.6	99.3	97.0	115.0	124.6	134.9	145.7	1.7
Canada	11.0	13.2	12.5	15.7	17.1	18.3	19.5	1.9
Mexico	5.0	6.2	6.0	7.5	8.7	10.3	12.7	3.2
Western Europe	**59.9**	**66.8**	**68.2**	**73.1**	**77.1**	**80.6**	**84.2**	**0.9**
United Kingdom	9.3	9.8	9.8	10.5	11.3	11.8	12.4	1.0
France	8.8	10.4	10.5	12.1	12.7	13.3	13.9	1.2
Germany	14.8	14.2	14.4	15.1	15.7	16.1	16.5	0.6
Italy	7.0	8.0	8.1	8.7	9.2	9.7	10.1	0.9
Netherlands	3.4	3.9	4.2	4.2	4.5	4.7	4.9	0.6
Other Western Europe	16.6	20.6	21.1	22.5	23.7	24.9	26.4	0.9
Industrialized Asia	**22.3**	**27.5**	**27.7**	**31.3**	**33.3**	**35.3**	**38.0**	**1.3**
Japan	17.9	21.8	21.9	24.4	25.7	26.8	28.3	1.1
Australia/New Zealand	4.4	5.7	5.8	6.9	7.7	8.5	9.7	2.1
Total Industrialized	**182.8**	**213.0**	**211.5**	**242.6**	**260.8**	**279.4**	**300.0**	**1.5**
EE/FSU								
Former Soviet Union	**60.7**	**40.8**	**41.9**	**50.0**	**56.9**	**64.9**	**73.7**	**2.4**
Russia	39.3	27.4	28.2	33.6	38.3	43.3	48.3	2.3
Other FSU	21.4	13.4	13.7	16.4	18.6	21.6	25.3	2.6
Eastern Europe	**15.6**	**11.3**	**11.4**	**13.5**	**15.0**	**17.1**	**18.6**	**2.1**
Total EE/FSU	**76.3**	**52.2**	**53.3**	**63.5**	**71.9**	**82.0**	**92.3**	**2.3**
Developing Countries								
Developing Asia	**52.5**	**80.5**	**85.0**	**116.8**	**143.1**	**173.1**	**204.8**	**3.7**
China	27.0	37.0	39.7	58.0	72.5	89.4	106.1	4.2
India	7.8	12.7	12.8	17.3	21.3	26.2	31.7	3.9
South Korea	3.8	7.9	8.1	10.7	12.3	13.9	15.7	2.8
Other Asia	13.9	23.0	24.5	30.8	37.0	43.5	51.3	3.1
Middle East	**13.1**	**20.3**	**20.8**	**26.1**	**30.5**	**35.5**	**41.6**	**2.9**
Turkey	2.0	3.0	2.9	3.9	4.6	5.3	6.2	3.2
Other Middle East	11.1	17.3	17.9	22.2	25.9	30.2	35.4	2.9
Africa	**9.3**	**11.9**	**12.4**	**15.7**	**19.2**	**23.9**	**28.4**	**3.5**
Central and South America	**14.4**	**21.0**	**20.9**	**26.5**	**30.6**	**35.8**	**42.8**	**3.0**
Brazil	6.0	9.0	8.8	10.9	12.9	15.1	18.0	3.0
Other Central/South America	8.5	12.0	12.2	15.6	17.7	20.7	24.8	3.0
Total Developing	**89.3**	**133.8**	**139.2**	**185.0**	**223.3**	**268.3**	**317.7**	**3.5**
Total World	**348.4**	**398.9**	**403.9**	**491.1**	**556.1**	**629.7**	**710.0**	**2.4**

[a]Includes the 50 States and the District of Columbia.

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 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table B1; and System for the Analysis of Global Energy Markets (2004).

Table B2. World Total Energy Consumption by Region and Fuel, High Economic Growth Case, 1990-2025
(Quadrillion Btu)

Region/Country	History			Projections				Average Annual Percent Change, 2001-2025
	1990	2000	2001	2010	2015	2020	2025	
Industrialized Countries								
North America								
Oil	40.4	46.3	45.9	55.2	61.3	66.6	72.9	1.9
Natural Gas	23.1	28.8	27.6	33.8	37.3	41.3	44.0	2.0
Coal	20.7	24.5	23.9	27.7	28.8	31.2	35.7	1.7
Nuclear	6.9	8.7	8.9	9.6	9.8	10.0	9.7	0.4
Other	9.5	10.6	9.4	12.0	13.2	14.4	15.6	2.1
Total	**100.6**	**118.7**	**115.6**	**138.2**	**150.4**	**163.5**	**177.9**	**1.8**
Western Europe								
Oil	25.8	28.5	28.9	31.1	32.3	33.6	34.5	0.7
Natural Gas	9.7	14.9	15.1	17.4	20.2	22.9	25.9	2.3
Coal	12.4	8.4	8.6	8.1	7.8	7.1	7.0	-0.9
Nuclear	7.4	8.8	9.1	9.5	9.4	8.9	7.9	-0.6
Other	4.5	6.0	6.1	7.0	7.4	8.1	8.8	1.5
Total	**59.9**	**66.8**	**68.2**	**73.1**	**77.1**	**80.6**	**84.2**	**0.9**
Industrialized Asia								
Oil	12.1	13.2	13.0	14.4	14.9	15.5	16.4	1.0
Natural Gas	2.5	4.0	4.1	4.8	5.4	6.0	6.9	2.2
Coal	4.2	5.7	5.9	6.5	7.0	7.5	8.2	1.4
Nuclear	2.0	3.0	3.2	3.8	4.0	4.4	4.2	1.2
Other	1.6	1.6	1.6	1.9	2.0	2.0	2.3	1.5
Total	**22.3**	**27.5**	**27.7**	**31.3**	**33.3**	**35.3**	**38.0**	**1.3**
Total Industrialized								
Oil	78.2	88.1	87.8	100.6	108.5	115.7	123.8	1.4
Natural Gas	35.4	47.7	46.8	55.9	63.0	70.2	76.8	2.1
Coal	37.3	38.6	38.5	42.3	43.6	45.8	50.9	1.2
Nuclear	16.3	20.5	21.2	22.9	23.2	23.3	21.9	0.1
Other	15.6	18.2	17.1	20.9	22.5	24.5	26.7	1.9
Total	**182.8**	**213.0**	**211.5**	**242.6**	**260.8**	**279.4**	**300.0**	**1.5**
EE/FSU								
Oil	21.0	10.9	11.0	13.7	16.7	20.5	24.5	3.4
Natural Gas	28.8	23.3	23.8	30.3	35.4	41.4	47.5	2.9
Coal	20.8	12.2	12.4	12.2	12.1	12.2	12.2	-0.1
Nuclear	2.9	3.0	3.1	3.4	3.5	3.2	2.9	-0.3
Other	2.8	3.0	3.2	3.8	4.3	4.8	5.2	2.1
Total	**76.3**	**52.2**	**53.3**	**63.5**	**71.9**	**82.0**	**92.3**	**2.3**
Developing Countries								
Developing Asia								
Oil	16.1	30.2	30.7	44.4	54.5	66.6	79.6	4.0
Natural Gas	3.2	6.9	7.9	10.6	13.4	17.2	22.0	4.3
Coal	29.1	37.1	39.4	50.9	60.5	71.8	84.1	3.2
Nuclear	0.9	1.7	1.8	3.1	4.2	4.9	5.1	4.4
Other	3.2	4.5	5.1	7.7	10.4	12.5	14.0	4.3
Total	**52.5**	**80.5**	**85.0**	**116.8**	**143.1**	**173.1**	**204.8**	**3.7**

See notes at end of table.

Table B2. World Total Energy Consumption by Region and Fuel, High Economic Growth Case, 1990-2025 (Continued)
(Quadrillion Btu)

Region/Country	History			Projections				Average Annual Percent Change, 2001-2025
	1990	2000	2001	2010	2015	2020	2025	
Developing Countries (Continued)								
Middle East								
Oil	8.0	11.0	11.1	14.8	17.2	20.2	23.5	3.2
Natural Gas	3.9	7.7	8.2	9.3	10.8	12.5	14.9	2.5
Coal	0.8	1.1	1.1	1.3	1.5	1.6	1.9	2.3
Nuclear	0.0	0.0	0.0	0.1	0.1	0.1	0.2	—
Other	0.4	0.5	0.4	0.6	0.8	1.0	1.2	4.7
Total	**13.1**	**20.3**	**20.8**	**26.1**	**30.5**	**35.5**	**41.6**	**2.9**
Africa								
Oil	4.2	5.2	5.3	7.1	9.0	12.0	14.3	4.2
Natural Gas	1.5	2.2	2.5	3.0	3.8	4.8	6.0	3.8
Coal	3.0	3.7	3.8	4.4	5.1	5.7	6.5	2.2
Nuclear	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1.2
Other	0.6	0.7	0.8	1.1	1.2	1.3	1.5	2.8
Total	**9.3**	**11.9**	**12.4**	**15.7**	**19.2**	**23.9**	**28.4**	**3.5**
Central and South America								
Oil	7.7	10.6	10.5	13.0	15.2	18.2	22.3	3.2
Natural Gas	2.2	3.6	3.8	5.1	6.5	8.2	10.6	4.4
Coal	0.6	0.9	0.8	1.1	1.2	1.4	1.6	2.9
Nuclear	0.1	0.1	0.2	0.2	0.2	0.2	0.2	-0.7
Other	3.9	5.9	5.6	7.0	7.4	7.8	8.1	1.6
Total	**14.4**	**21.0**	**20.9**	**26.5**	**30.6**	**35.8**	**42.8**	**3.0**
Total Developing Countries								
Oil	35.9	56.9	57.6	79.3	96.0	117.1	139.7	3.8
Natural Gas	10.8	20.4	22.4	28.0	34.4	42.7	53.4	3.7
Coal	33.5	42.8	45.1	57.7	68.3	80.6	94.0	3.1
Nuclear	1.1	2.0	2.2	3.5	4.7	5.4	5.7	4.1
Other	8.0	11.6	11.8	16.4	19.8	22.5	24.9	3.1
Total	**89.3**	**133.8**	**139.2**	**185.0**	**223.3**	**268.3**	**317.7**	**3.5**
Total World								
Oil	135.1	155.9	156.5	193.6	221.3	253.2	287.9	2.6
Natural Gas	75.0	91.4	93.1	114.2	132.7	154.3	177.7	2.7
Coal	91.6	93.6	95.9	112.3	124.0	138.6	157.1	2.1
Nuclear	20.3	25.5	26.4	29.8	31.4	31.8	30.4	0.6
Other	26.4	32.8	32.2	41.1	46.6	51.8	56.7	2.4
Total	**348.4**	**398.9**	**403.9**	**491.1**	**556.1**	**629.7**	**710.0**	**2.4**

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 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table B1; and System for the Analysis of Global Energy Markets (2004).

Table B3. World Gross Domestic Product (GDP) by Region, High Economic Growth Case, 1990-2025
(Billion 1997 Dollars)

Region/Country	History			Projections				Average Annual Percent Change, 2001-2025
	1990	2000	2001	2010	2015	2020	2025	
Industrialized Countries								
North America	**7,723**	**10,573**	**10,609**	**14,744**	**17,333**	**20,295**	**23,946**	**3.5**
United States[a]	6,839	9,370	9,394	13,109	15,377	17,946	21,088	3.4
Canada	553	737	751	1,016	1,190	1,380	1,590	3.2
Mexico	331	465	464	620	766	969	1,267	4.3
Western Europe	**7,635**	**9,356**	**9,513**	**11,759**	**13,403**	**15,272**	**17,372**	**2.5**
United Kingdom	1,153	1,461	1,492	1,926	2,238	2,585	2,980	2.9
France	1,300	1,568	1,601	1,984	2,263	2,591	2,972	2.6
Germany	1,917	2,261	2,284	2,702	3,012	3,357	3,731	2.1
Italy	1,063	1,248	1,269	1,545	1,744	1,976	2,228	2.4
Netherlands	317	423	428	514	583	665	760	2.4
Other Western Europe	1,885	2,396	2,440	3,089	3,562	4,097	4,699	2.8
Industrialized Asia	**4,189**	**4,925**	**4,955**	**6,016**	**6,790**	**7,629**	**8,552**	**2.3**
Japan	3,808	4,395	4,411	5,273	5,906	6,584	7,325	2.1
Australia/New Zealand	381	530	543	742	884	1,045	1,227	3.5
Total Industrialized	**19,546**	**24,854**	**25,077**	**32,520**	**37,526**	**43,197**	**49,869**	**2.9**
EE/FSU								
Former Soviet Union	**929**	**597**	**632**	**1,108**	**1,466**	**1,901**	**2,420**	**5.8**
Russia	668	449	471	791	1,027	1,312	1,644	5.3
Other FSU	261	148	161	317	439	589	776	6.8
Eastern Europe	**353**	**379**	**389**	**595**	**757**	**963**	**1,212**	**4.8**
Total EE/FSU	**1,282**	**976**	**1,022**	**1,703**	**2,223**	**2,865**	**3,632**	**5.4**
Developing Countries								
Developing Asia	**1,766**	**3,403**	**3,536**	**6,296**	**8,505**	**11,199**	**14,543**	**6.1**
China	428	1,120	1,202	2,418	3,390	4,624	6,222	7.1
India	290	492	520	908	1,232	1,655	2,208	6.2
South Korea	299	544	562	973	1,255	1,545	1,869	5.1
Other Asia	749	1,246	1,253	1,997	2,628	3,375	4,244	5.2
Middle East	**409**	**594**	**584**	**857**	**1,081**	**1,352**	**1,675**	**4.5**
Turkey	139	198	183	273	350	445	558	4.8
Other Middle East	270	396	400	583	731	907	1,117	4.4
Africa	**488**	**606**	**626**	**979**	**1,253**	**1,590**	**1,999**	**5.0**
Central and South America	**1,105**	**1,503**	**1,510**	**2,127**	**2,743**	**3,528**	**4,553**	**4.7**
Brazil	655	851	863	1,230	1,584	2,028	2,603	4.7
Other Central/South America	450	652	647	898	1,159	1,500	1,951	4.7
Total Developing	**3,767**	**6,106**	**6,256**	**10,260**	**13,582**	**17,669**	**22,771**	**5.5**
Total World	**24,596**	**31,937**	**32,354**	**44,482**	**53,331**	**63,731**	**76,272**	**3.6**

[a]Includes the 50 States and the District of Columbia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding.

Sources: Global Insight, Inc., *World Economic Outlook*, Vol. 1 (Lexington, MA, Third Quarter 2003), and Energy Information Administration, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table B20.

Table B4. World Oil Consumption by Region, High Economic Growth Case, 1990-2025
(Million Barrels per Day)

Region/Country	History			Projections				Average Annual Percent Change, 2001-2025
	1990	2000	2001	2010	2015	2020	2025	
Industrialized Countries								
North America	**20.4**	**23.8**	**23.5**	**28.3**	**31.5**	**34.2**	**37.5**	**2.0**
United States[a]	17.0	19.7	19.6	23.6	26.2	28.4	30.6	1.9
Canada	1.7	2.1	1.9	2.3	2.5	2.8	3.0	1.9
Mexico	1.7	2.0	1.9	2.4	2.8	3.1	3.9	2.9
Western Europe	**12.5**	**13.8**	**14.0**	**15.0**	**15.6**	**16.2**	**16.7**	**0.7**
United Kingdom	1.8	1.7	1.7	1.9	2.0	2.1	2.3	1.3
France	1.8	2.0	2.0	2.1	2.2	2.2	2.3	0.5
Germany	2.7	2.8	2.8	3.0	3.2	3.4	3.5	0.9
Italy	1.9	1.9	1.9	2.1	2.1	2.2	2.3	0.9
Netherlands	0.7	0.9	0.9	0.9	1.0	1.0	1.0	0.6
Other Western Europe	3.6	4.6	4.7	5.0	5.1	5.3	5.3	0.5
Industrialized Asia	**6.0**	**6.5**	**6.4**	**7.1**	**7.4**	**7.7**	**8.1**	**1.0**
Japan	5.1	5.5	5.4	5.8	5.9	6.0	6.3	0.6
Australia/New Zealand	0.8	1.0	1.0	1.3	1.5	1.7	1.9	2.6
Total Industrialized	**38.8**	**44.1**	**43.9**	**50.5**	**54.5**	**58.1**	**62.3**	**1.5**
EE/FSU								
Former Soviet Union	**8.4**	**3.8**	**3.9**	**4.9**	**6.1**	**7.7**	**9.3**	**3.7**
Russia	5.4	2.6	2.6	3.3	4.1	5.1	6.2	3.7
Other FSU	3.0	1.2	1.3	1.6	2.1	2.6	3.1	3.7
Eastern Europe	**1.6**	**1.4**	**1.4**	**1.7**	**1.9**	**2.2**	**2.5**	**2.4**
Total EE/FSU	**10.0**	**5.2**	**5.3**	**6.6**	**8.0**	**9.9**	**11.8**	**3.4**
Developing Countries								
Developing Asia	**7.6**	**14.5**	**14.8**	**21.4**	**26.3**	**32.1**	**38.3**	**4.0**
China	2.3	4.8	5.0	8.1	10.2	12.8	15.2	4.8
India	1.2	2.1	2.1	3.0	3.9	5.1	6.5	4.7
South Korea	1.0	2.1	2.1	2.7	2.9	3.2	3.5	2.1
Other Asia	3.1	5.5	5.5	7.6	9.2	11.0	13.1	3.7
Middle East	**3.8**	**5.3**	**5.4**	**7.2**	**8.4**	**9.8**	**11.4**	**3.2**
Turkey	0.5	0.7	0.6	0.9	1.0	1.2	1.4	3.4
Other Middle East	3.4	4.7	4.7	6.3	7.3	8.6	10.0	3.2
Africa	**2.1**	**2.5**	**2.6**	**3.5**	**4.4**	**5.8**	**7.0**	**4.2**
Central and South America	**3.7**	**5.2**	**5.2**	**6.4**	**7.5**	**9.0**	**10.9**	**3.2**
Brazil	1.5	2.2	2.2	2.6	3.1	3.7	4.5	3.0
Other Central/South America	2.3	3.0	3.0	3.8	4.4	5.3	6.4	3.3
Total Developing	**17.3**	**27.6**	**27.9**	**38.4**	**46.5**	**56.7**	**67.6**	**3.8**
Total World	**66.1**	**76.9**	**77.1**	**95.4**	**109.0**	**124.7**	**141.7**	**2.6**

[a]Includes the 50 States and the District of Columbia.

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 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table B21; and System for the Analysis of Global Energy Markets (2004).

Table B5. World Natural Gas Consumption by Region, High Economic Growth Case, 1990-2025
(Trillion Cubic Feet)

Region/Country	History 1990	History 2000	History 2001	Projections 2010	Projections 2015	Projections 2020	Projections 2025	Average Annual Percent Change, 2001-2025
Industrialized Countries								
North America	**22.5**	**28.1**	**26.9**	**32.9**	**36.3**	**40.2**	**42.9**	**2.0**
United States[a]	19.2	23.5	22.6	27.2	29.8	32.5	33.8	1.7
Canada	2.4	3.3	2.9	4.0	4.4	4.8	5.3	2.5
Mexico	0.9	1.4	1.4	1.7	2.2	2.9	3.7	4.3
Western Europe	**10.1**	**14.6**	**14.8**	**17.0**	**19.8**	**22.4**	**25.3**	**2.3**
United Kingdom	2.1	3.4	3.3	3.9	4.7	5.2	5.6	2.2
France	1.0	1.4	1.5	1.6	1.8	1.8	1.9	1.1
Germany	2.7	3.2	3.3	3.7	4.5	5.6	6.0	2.5
Italy	1.7	2.5	2.5	2.9	3.3	3.6	3.8	1.7
Netherlands	1.5	1.7	1.8	1.8	2.1	2.3	2.4	1.3
Other Western Europe	1.2	2.3	2.4	3.0	3.3	3.7	5.7	3.6
Industrialized Asia	**2.6**	**3.8**	**3.9**	**4.5**	**5.2**	**5.7**	**6.6**	**2.2**
Japan	1.9	2.8	2.8	3.3	3.8	4.1	4.6	2.1
Australia/New Zealand	0.8	1.0	1.1	1.2	1.4	1.6	1.9	2.5
Total Industrialized	**35.2**	**46.4**	**45.6**	**54.4**	**61.3**	**68.3**	**74.7**	**2.1**
EE/FSU								
Former Soviet Union	**25.0**	**20.5**	**20.8**	**25.7**	**29.7**	**34.2**	**39.3**	**2.7**
Russia	17.3	14.1	14.4	17.4	19.9	22.6	25.4	2.4
Other FSU	7.7	6.4	6.4	8.3	9.8	11.6	13.9	3.3
Eastern Europe	**3.1**	**2.4**	**2.7**	**4.2**	**5.2**	**6.7**	**7.5**	**4.4**
Total EE/FSU	**28.1**	**23.0**	**23.5**	**29.9**	**34.9**	**40.8**	**46.8**	**2.9**
Developing Countries								
Developing Asia	**3.0**	**6.6**	**7.5**	**10.0**	**12.6**	**16.1**	**20.5**	**4.2**
China	0.5	1.0	1.0	2.0	2.9	4.2	5.8	7.6
India	0.4	0.8	0.8	1.3	1.7	2.2	2.9	5.5
South Korea	0.1	0.7	0.7	1.0	1.4	1.8	2.3	4.8
Other Asia	2.0	4.2	4.9	5.6	6.6	7.9	9.5	2.8
Middle East	**3.7**	**7.3**	**7.9**	**8.9**	**10.3**	**12.0**	**14.2**	**2.5**
Turkey	0.1	0.5	0.6	0.8	1.0	1.2	1.3	3.6
Other Middle East	3.6	6.8	7.3	8.1	9.3	10.8	12.9	2.4
Africa	**1.4**	**2.0**	**2.3**	**2.8**	**3.5**	**4.4**	**5.5**	**3.8**
Central and South America	**2.0**	**3.3**	**3.5**	**4.7**	**6.0**	**7.6**	**9.8**	**4.4**
Brazil	0.1	0.3	0.3	1.0	1.7	2.3	3.0	9.5
Other Central/South America	1.9	3.0	3.2	3.7	4.3	5.3	6.8	3.2
Total Developing	**10.1**	**19.3**	**21.2**	**26.3**	**32.3**	**40.0**	**50.0**	**3.6**
Total World	**73.4**	**88.7**	**90.3**	**110.7**	**128.5**	**149.1**	**171.5**	**2.7**

[a]Includes the 50 States and the District of Columbia.

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 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table B13; and System for the Analysis of Global Energy Markets (2004).

Table B6. World Coal Consumption by Region, High Economic Growth Case, 1990-2025
(Million Short Tons)

Region/Country	History			Projections				Average Annual Percent Change, 2001-2025
	1990	2000	2001	2010	2015	2020	2025	
Industrialized Countries								
North America	**971**	**1,168**	**1,148**	**1,338**	**1,401**	**1,515**	**1,737**	**1.7**
United States[a]	903	1,084	1,060	1,240	1,295	1,399	1,612	1.8
Canada	59	69	73	79	85	93	99	1.3
Mexico	9	15	15	19	22	24	26	2.4
Western Europe	**894**	**559**	**574**	**541**	**518**	**475**	**467**	**-0.9**
United Kingdom	119	64	71	69	66	56	50	-1.5
France	35	25	21	13	12	12	11	-2.7
Germany	528	264	265	272	254	235	234	-0.5
Italy	25	20	22	22	22	20	20	-0.5
Netherlands	15	14	23	18	17	16	16	-1.6
Other Western Europe	172	172	172	155	152	144	149	-0.6
Industrialized Asia	**231**	**303**	**312**	**345**	**370**	**398**	**438**	**1.4**
Japan	125	160	166	182	192	205	218	1.1
Australia/New Zealand	106	143	147	163	178	192	221	1.7
Total Industrialized	**2,095**	**2,029**	**2,034**	**2,225**	**2,290**	**2,388**	**2,643**	**1.1**
EE/FSU								
Former Soviet Union	**848**	**421**	**446**	**458**	**457**	**471**	**481**	**0.3**
Russia	497	267	284	310	314	323	329	0.6
Other FSU	352	154	162	148	143	148	153	-0.2
Eastern Europe	**528**	**390**	**382**	**352**	**341**	**328**	**317**	**-0.8**
Total EE/FSU	**1,376**	**811**	**828**	**810**	**798**	**799**	**798**	**-0.2**
Developing Countries								
Developing Asia	**1,590**	**1,959**	**2,084**	**2,697**	**3,216**	**3,821**	**4,478**	**3.2**
China	1,124	1,282	1,383	1,844	2,249	2,714	3,221	3.6
India	242	359	360	450	522	604	694	2.8
South Korea	49	72	76	110	127	142	160	3.2
Other Asia	175	246	265	293	318	361	403	1.8
Middle East	**66**	**94**	**95**	**117**	**128**	**144**	**164**	**2.3**
Turkey	60	80	81	97	109	123	141	2.3
Other Middle East	6	14	14	20	19	21	23	2.2
Africa	**152**	**187**	**191**	**219**	**255**	**287**	**325**	**2.2**
Central and South America	**27**	**34**	**32**	**45**	**49**	**55**	**62**	**2.9**
Brazil	17	21	21	31	33	36	41	2.9
Other Central/South America	10	13	11	14	16	19	21	2.8
Total Developing	**1,835**	**2,275**	**2,401**	**3,078**	**3,647**	**4,306**	**5,029**	**3.1**
Total World	**5,307**	**5,115**	**5,263**	**6,113**	**6,735**	**7,493**	**8,470**	**2.0**

[a]Includes the 50 States and the District of Columbia.

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 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table B16; and System for the Analysis of Global Energy Markets (2004).

Table B7. World Nuclear Energy Consumption by Region, High Economic Growth Case, 1990-2025
(Billion Kilowatthours)

Region/Country	History			Projections				Average Annual Percent Change, 2001-2025
	1990	2000	2001	2010	2015	2020	2025	
Industrialized Countries								
North America	**649**	**830**	**850**	**912**	**932**	**945**	**925**	**0.4**
United States[a]	577	754	769	794	812	816	816	0.3
Canada	69	69	73	108	110	118	98	1.2
Mexico	3	8	8	10	10	11	11	1.1
Western Europe	**703**	**845**	**870**	**906**	**897**	**855**	**760**	**-0.6**
United Kingdom	59	82	86	69	52	47	28	-4.6
France	298	394	401	447	478	520	550	1.3
Germany	145	161	163	137	107	15	0	-100.0
Italy	0	0	0	0	0	0	0	—
Netherlands	3	4	4	4	4	0	0	-100.0
Other Western Europe	198	204	217	248	257	273	182	-0.7
Industrialized Asia	**192**	**294**	**309**	**369**	**394**	**426**	**411**	**1.2**
Japan	192	294	309	369	394	426	411	1.2
Australia/New Zealand	0	0	0	0	0	0	0	—
Total Industrialized	**1,544**	**1,969**	**2,029**	**2,187**	**2,223**	**2,226**	**2,095**	**0.1**
EE/FSU								
Former Soviet Union	**201**	**204**	**210**	**236**	**236**	**204**	**174**	**-0.8**
Russia	115	122	125	141	154	129	100	-1.0
Other FSU	86	81	85	95	82	76	75	-0.5
Eastern Europe	**54**	**67**	**72**	**76**	**80**	**84**	**88**	**0.8**
Total EE/FSU	**256**	**270**	**282**	**312**	**316**	**288**	**262**	**-0.3**
Developing Countries								
Developing Asia	**88**	**171**	**178**	**299**	**406**	**473**	**497**	**4.4**
China	0	16	17	66	129	142	154	9.7
India	6	14	18	46	55	66	66	5.5
South Korea	50	104	107	141	171	209	220	3.1
Other Asia	32	37	36	47	51	55	56	1.8
Middle East	**0**	**0**	**0**	**5**	**14**	**14**	**21**	**—**
Turkey	0	0	0	0	0	0	0	—
Other Middle East	0	0	0	5	14	14	21	—
Africa	**8**	**13**	**11**	**14**	**14**	**14**	**14**	**1.2**
Central and South America	**9**	**11**	**21**	**21**	**21**	**18**	**18**	**-0.7**
Brazil	2	5	14	14	14	14	14	-0.1
Other Central/South America	7	6	7	7	7	4	4	-2.4
Total Developing	**105**	**195**	**209**	**339**	**455**	**518**	**549**	**4.1**
Total World	**1,905**	**2,434**	**2,521**	**2,838**	**2,994**	**3,032**	**2,906**	**0.6**

[a]Includes the 50 States and the District of Columbia.

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 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table B8; and System for the Analysis of Global Energy Markets (2004).

Table B8. World Consumption of Hydroelectricity and Other Renewable Energy by Region, High Economic Growth Case, 1990-2025
(Quadrillion Btu)

Region/Country	History			Projections				Average Annual Percent Change, 2001-2025
	1990	2000	2001	2010	2015	2020	2025	
Industrialized Countries								
North America	**9.5**	**10.6**	**9.4**	**12.0**	**13.2**	**14.4**	**15.6**	**2.1**
United States[a]	6.0	6.4	5.5	7.5	8.3	9.3	10.2	2.6
Canada	3.1	3.8	3.5	3.9	4.3	4.5	4.7	1.3
Mexico	0.3	0.5	0.4	0.5	0.6	0.6	0.7	2.2
Western Europe	**4.5**	**6.0**	**6.1**	**7.0**	**7.4**	**8.1**	**8.8**	**1.5**
United Kingdom	0.1	0.1	0.1	0.2	0.2	0.2	0.4	5.9
France	0.6	0.7	0.8	0.9	0.9	1.0	1.1	1.2
Germany	0.3	0.4	0.5	0.6	0.7	0.6	0.7	1.6
Italy	0.4	0.6	0.6	0.9	0.9	0.9	1.0	2.1
Netherlands	0.0	0.1	0.1	0.2	0.2	0.2	0.2	6.6
Other Western Europe	3.2	4.1	4.1	4.2	4.6	5.1	5.4	1.2
Industrialized Asia	**1.6**	**1.6**	**1.6**	**1.9**	**2.0**	**2.0**	**2.3**	**1.5**
Japan	1.1	1.1	1.1	1.3	1.4	1.4	1.7	1.7
Australia/New Zealand	0.4	0.5	0.5	0.5	0.6	0.6	0.6	1.1
Total Industrialized	**15.6**	**18.2**	**17.1**	**20.9**	**22.5**	**24.5**	**26.7**	**1.9**
EE/FSU								
Former Soviet Union	**2.4**	**2.3**	**2.5**	**3.0**	**3.3**	**3.6**	**3.9**	**1.8**
Russia	1.8	1.7	1.8	2.1	2.2	2.5	2.7	1.6
Other FSU	0.6	0.7	0.7	0.9	1.0	1.1	1.2	2.4
Eastern Europe	**0.4**	**0.6**	**0.6**	**0.8**	**1.0**	**1.2**	**1.3**	**2.8**
Total EE/FSU	**2.8**	**3.0**	**3.2**	**3.8**	**4.3**	**4.8**	**5.2**	**2.1**
Developing Countries								
Developing Asia	**3.2**	**4.5**	**5.1**	**7.7**	**10.4**	**12.5**	**14.0**	**4.3**
China	1.3	2.3	2.8	4.5	5.6	7.0	7.4	4.2
India	0.7	0.8	0.8	1.1	1.4	1.7	2.0	3.8
South Korea	0.0	0.0	0.0	0.1	0.1	0.1	0.1	6.0
Other Asia	1.1	1.4	1.5	2.0	3.4	3.7	4.5	4.7
Middle East	**0.4**	**0.5**	**0.4**	**0.6**	**0.8**	**1.0**	**1.2**	**4.7**
Turkey	0.2	0.3	0.3	0.4	0.5	0.6	0.7	4.5
Other Middle East	0.1	0.1	0.1	0.2	0.3	0.4	0.5	5.2
Africa	**0.6**	**0.7**	**0.8**	**1.1**	**1.2**	**1.3**	**1.5**	**2.8**
Central and South America	**3.9**	**5.9**	**5.6**	**7.0**	**7.4**	**7.8**	**8.1**	**1.6**
Brazil	2.2	3.3	2.9	3.7	3.9	4.2	4.6	1.9
Other Central/South America	1.7	2.6	2.7	3.3	3.5	3.5	3.5	1.2
Total Developing	**8.0**	**11.6**	**11.8**	**16.4**	**19.8**	**22.5**	**24.9**	**3.1**
Total World	**26.4**	**32.8**	**32.2**	**41.1**	**46.6**	**51.8**	**56.7**	**2.4**

[a]Includes the 50 States and the District of Columbia.

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 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table B1; and System for the Analysis of Global Energy Markets (2004).

Table B9. World Carbon Dioxide Emissions by Region, High Economic Growth Case, 1990-2025
(Million Metric Tons Carbon Dioxide)

Region/Country	History 1990	History 2000	History 2001	Projections 2010	Projections 2015	Projections 2020	Projections 2025	Average Annual Percent Change, 2001-2025
Industrialized Countries								
North America	**5,769**	**6,731**	**6,613**	**7,870**	**8,557**	**9,316**	**10,267**	**1.9**
United States[a]	4,989	5,787	5,692	6,730	7,281	7,886	8,615	1.7
Canada	473	581	569	699	761	826	900	1.9
Mexico	308	364	352	441	515	603	753	3.2
Western Europe	**3,412**	**3,442**	**3,465**	**3,671**	**3,864**	**4,028**	**4,237**	**0.8**
United Kingdom	600	553	563	619	671	697	728	1.1
France	374	401	396	401	417	423	435	0.4
Germany	995	828	819	872	909	976	1,003	0.8
Italy	415	443	445	495	527	549	568	1.0
Netherlands	211	228	248	238	255	263	270	0.4
Other Western Europe	816	989	994	1,046	1,086	1,121	1,234	0.9
Industrialized Asia	**1,280**	**1,526**	**1,556**	**1,737**	**1,850**	**1,961**	**2,129**	**1.3**
Japan	987	1,138	1,158	1,268	1,327	1,379	1,466	1.0
Australia/New Zealand	294	387	398	469	523	582	663	2.1
Total Industrialized	**10,462**	**11,699**	**11,634**	**13,278**	**14,271**	**15,305**	**16,633**	**1.5**
EE/FSU								
Former Soviet Union	**3,798**	**2,338**	**2,399**	**2,826**	**3,216**	**3,699**	**4,219**	**2.4**
Russia	2,405	1,570	1,614	1,911	2,171	2,474	2,784	2.3
Other FSU	1,393	767	785	915	1,045	1,225	1,435	2.5
Eastern Europe	**1,104**	**756**	**748**	**831**	**899**	**1,001**	**1,076**	**1.5**
Total EE/FSU	**4,902**	**3,094**	**3,148**	**3,658**	**4,115**	**4,699**	**5,295**	**2.2**
Developing Countries								
Developing Asia	**3,994**	**5,709**	**6,012**	**8,081**	**9,763**	**11,775**	**13,981**	**3.6**
China	2,262	2,861	3,050	4,309	5,328	6,542	7,821	4.0
India	561	914	917	1,205	1,465	1,785	2,152	3.6
South Korea	234	425	443	594	682	765	872	2.9
Other Asia	937	1,509	1,602	1,973	2,288	2,684	3,136	2.8
Middle East	**846**	**1,262**	**1,299**	**1,635**	**1,896**	**2,210**	**2,580**	**2.9**
Turkey	129	184	184	261	300	348	407	3.4
Other Middle East	717	1,078	1,115	1,373	1,597	1,862	2,173	2.8
Africa	**656**	**811**	**843**	**1,046**	**1,285**	**1,600**	**1,897**	**3.4**
Central and South America	**703**	**961**	**964**	**1,227**	**1,453**	**1,757**	**2,166**	**3.4**
Brazil	250	343	347	459	561	678	833	3.7
Other Central/South America	453	618	617	768	892	1,079	1,332	3.3
Total Developing	**6,200**	**8,744**	**9,118**	**11,989**	**14,398**	**17,341**	**20,623**	**3.5**
Total World	**21,563**	**23,536**	**23,899**	**28,925**	**32,784**	**37,345**	**42,551**	**2.4**

[a]Includes the 50 States and the District of Columbia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. The U.S. numbers include carbon dioxide emissions attributable to renewable energy sources.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table B19; and System for the Analysis of Global Energy Markets (2004).

Table B10. World Carbon Dioxide Emissions from Oil Use by Region, High Economic Growth Case, 1990-2025
(Million Metric Tons Carbon Dioxide)

Region/Country	History			Projections				Average Annual Percent Change, 2001-2025
	1990	2000	2001	2010	2015	2020	2025	
Industrialized Countries								
North America	**2,626**	**2,935**	**2,967**	**3,506**	**3,898**	**4,224**	**4,613**	**1.9**
United States[a]	2,165	2,416	2,458	2,876	3,197	3,449	3,709	1.7
Canada	222	258	258	317	344	373	405	1.9
Mexico	239	261	251	313	357	403	499	2.9
Western Europe	**1,739**	**1,853**	**1,845**	**1,983**	**2,058**	**2,142**	**2,203**	**0.7**
United Kingdom	242	231	231	257	267	286	311	1.3
France	245	267	267	281	288	294	302	0.5
Germany	376	357	348	373	392	419	430	0.9
Italy	270	261	261	290	299	308	321	0.9
Netherlands	99	98	98	101	105	108	112	0.6
Other Western Europe	507	639	639	682	706	726	727	0.5
Industrialized Asia	**768**	**802**	**802**	**892**	**928**	**962**	**1,019**	**1.0**
Japan	655	667	668	717	732	741	772	0.6
Australia/New Zealand	113	134	134	174	196	221	247	2.6
Total Industrialized	**5,133**	**5,589**	**5,613**	**6,381**	**6,884**	**7,328**	**7,835**	**1.4**
EE/FSU								
Former Soviet Union	**1,224**	**547**	**557**	**703**	**880**	**1,099**	**1,325**	**3.7**
Russia	783	366	369	465	582	727	876	3.7
Other FSU	441	181	189	238	298	372	449	3.7
Eastern Europe	**243**	**189**	**189**	**223**	**253**	**292**	**335**	**2.4**
Total EE/FSU	**1,468**	**736**	**746**	**925**	**1,133**	**1,390**	**1,661**	**3.4**
Developing Countries								
Developing Asia	**1,116**	**1,912**	**1,953**	**2,823**	**3,465**	**4,233**	**5,056**	**4.0**
China	345	619	642	1,046	1,318	1,654	1,967	4.8
India	165	279	279	391	509	667	850	4.7
South Korea	138	239	245	304	336	361	399	2.1
Other Asia	468	775	787	1,082	1,302	1,550	1,840	3.6
Middle East	**568**	**753**	**764**	**1,020**	**1,191**	**1,397**	**1,620**	**3.2**
Turkey	64	81	81	115	134	155	181	3.4
Other Middle East	504	672	682	906	1,057	1,242	1,440	3.2
Africa	**304**	**356**	**366**	**490**	**623**	**827**	**990**	**4.2**
Central and South America	**533**	**694**	**691**	**853**	**999**	**1,196**	**1,462**	**3.2**
Brazil	210	276	280	334	391	470	574	3.0
Other Central/South America	323	418	411	519	608	726	887	3.3
Total Developing	**2,521**	**3,716**	**3,774**	**5,187**	**6,278**	**7,652**	**9,128**	**3.7**
Total World	**9,121**	**10,041**	**10,134**	**12,493**	**14,295**	**16,370**	**18,624**	**2.6**

[a]Includes the 50 States and the District of Columbia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table B19; and System for the Analysis of Global Energy Markets (2004).

Table B11. World Carbon Dioxide Emissions from Natural Gas Use by Region, High Economic Growth Case, 1990-2025
(Million Metric Tons Carbon Dioxide)

Region/Country	History			Projections				Average Annual Percent Change, 2001-2025
	1990	2000	2001	2010	2015	2020	2025	
Industrialized Countries								
North America	**1,207**	**1,503**	**1,421**	**1,776**	**1,961**	**2,170**	**2,315**	**2.1**
United States[a]	1,025	1,249	1,189	1,466	1,604	1,753	1,823	1.8
Canada	127	177	156	214	236	256	283	2.5
Mexico	54	77	77	96	121	161	209	4.3
Western Europe	**514**	**786**	**799**	**916**	**1,068**	**1,209**	**1,367**	**2.3**
United Kingdom	110	188	183	218	264	292	312	2.2
France	57	81	85	92	103	104	111	1.1
Germany	116	165	173	193	231	293	310	2.5
Italy	91	135	136	157	180	197	203	1.7
Netherlands	72	81	83	86	101	109	112	1.3
Other Western Europe	67	134	139	171	190	214	319	3.5
Industrialized Asia	**133**	**209**	**216**	**251**	**286**	**317**	**364**	**2.2**
Japan	89	152	157	185	208	225	256	2.1
Australia/New Zealand	44	57	59	66	78	92	108	2.5
Total Industrialized	**1,853**	**2,497**	**2,436**	**2,943**	**3,316**	**3,696**	**4,046**	**2.1**
EE/FSU								
Former Soviet Union	**1,352**	**1,103**	**1,119**	**1,381**	**1,595**	**1,836**	**2,113**	**2.7**
Russia	928	753	768	924	1,060	1,203	1,354	2.4
Other FSU	424	351	351	456	535	633	759	3.3
Eastern Europe	**167**	**127**	**139**	**222**	**271**	**349**	**393**	**4.4**
Total EE/FSU	**1,519**	**1,231**	**1,258**	**1,602**	**1,866**	**2,185**	**2,506**	**2.9**
Developing Countries								
Developing Asia	**167**	**366**	**419**	**560**	**707**	**909**	**1,160**	**4.3**
China	31	59	66	140	201	291	399	7.8
India	24	43	44	72	94	122	158	5.5
South Korea	6	40	44	65	87	114	146	5.2
Other Asia	106	225	266	282	325	382	458	2.3
Middle East	**205**	**406**	**435**	**490**	**570**	**661**	**785**	**2.5**
Turkey	7	29	31	61	70	85	102	5.1
Other Middle East	199	377	404	429	500	576	683	2.2
Africa	**80**	**116**	**130**	**157**	**198**	**251**	**315**	**3.8**
Central and South America	**116**	**188**	**200**	**271**	**342**	**434**	**561**	**4.4**
Brazil	6	18	19	54	94	124	164	9.5
Other Central/South America	110	170	182	216	248	310	397	3.3
Total Developing	**569**	**1,077**	**1,184**	**1,477**	**1,818**	**2,254**	**2,821**	**3.7**
Total World	**3,941**	**4,805**	**4,878**	**6,023**	**7,000**	**8,134**	**9,373**	**2.8**

[a]Includes the 50 States and the District of Columbia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table B19; and System for the Analysis of Global Energy Markets (2004).

Table B12. World Carbon Dioxide Emissions from Coal Use by Region, High Economic Growth Case, 1990-2025
(Million Metric Tons Carbon Dioxide)

Region/Country	History			Projections				Average Annual Percent Change, 2001-2025
	1990	2000	2001	2010	2015	2020	2025	
Industrialized Countries								
North America	**1,933**	**2,293**	**2,237**	**2,588**	**2,698**	**2,922**	**3,340**	**1.7**
United States[a]	1,794	2,122	2,057	2,388	2,480	2,684	3,084	1.7
Canada	123	146	155	168	181	198	212	1.3
Mexico	15	25	25	32	36	40	44	2.4
Western Europe	**1,159**	**804**	**821**	**771**	**739**	**677**	**666**	**-0.9**
United Kingdom	248	134	149	145	140	119	105	-1.5
France	72	52	44	28	26	25	23	-2.7
Germany	503	306	298	305	285	264	263	-0.5
Italy	54	48	49	48	48	44	43	-0.5
Netherlands	40	49	67	51	49	45	45	-1.6
Other Western Europe	242	216	215	194	191	180	187	-0.6
Industrialized Asia	**380**	**515**	**539**	**594**	**635**	**682**	**747**	**1.4**
Japan	243	319	334	366	387	413	438	1.1
Australia/New Zealand	137	196	205	228	249	269	309	1.7
Total Industrialized	**3,472**	**3,613**	**3,581**	**3,954**	**4,072**	**4,281**	**4,753**	**1.2**
EE/FSU								
Former Soviet Union	**1,222**	**687**	**723**	**743**	**742**	**764**	**780**	**0.3**
Russia	694	452	478	521	529	544	553	0.6
Other FSU	528	236	245	221	212	220	227	-0.3
Eastern Europe	**694**	**440**	**420**	**387**	**374**	**360**	**348**	**-0.8**
Total EE/FSU	**1,915**	**1,127**	**1,143**	**1,130**	**1,116**	**1,124**	**1,129**	**-0.1**
Developing Countries								
Developing Asia	**2,710**	**3,431**	**3,639**	**4,699**	**5,590**	**6,633**	**7,764**	**3.2**
China	1,886	2,183	2,342	3,123	3,809	4,597	5,455	3.6
India	371	592	594	743	862	996	1,145	2.8
South Korea	90	146	155	224	259	289	326	3.2
Other Asia	363	509	549	609	661	752	838	1.8
Middle East	**73**	**103**	**100**	**124**	**135**	**152**	**174**	**2.3**
Turkey	59	74	71	86	96	108	124	2.3
Other Middle East	14	29	29	38	40	45	50	2.3
Africa	**272**	**339**	**347**	**399**	**464**	**522**	**592**	**2.2**
Central and South America	**54**	**78**	**73**	**103**	**112**	**127**	**143**	**2.9**
Brazil	34	49	48	71	76	84	96	2.9
Other Central/South America	20	30	25	32	36	43	48	2.8
Total Developing	**3,110**	**3,951**	**4,160**	**5,325**	**6,302**	**7,435**	**8,674**	**3.1**
Total World	**8,497**	**8,691**	**8,884**	**10,409**	**11,490**	**12,841**	**14,555**	**2.1**

[a]Includes the 50 States and the District of Columbia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table B19; and System for the Analysis of Global Energy Markets (2004).

Table B13. World Total Energy Consumption in Oil-Equivalent Units by Region, High Economic Growth Case, 1990-2025
(Million Tons Oil Equivalent)

Region/Country	History			Projections				Average Annual Percent Change, 2001-2025
	1990	2000	2001	2010	2015	2020	2025	
Industrialized Countries								
North America	**2,534**	**2,990**	**2,912**	**3,483**	**3,791**	**4,120**	**4,483**	**1.8**
United States[a]	2,131	2,503	2,446	2,898	3,140	3,399	3,672	1.7
Canada	278	331	315	396	430	462	490	1.9
Mexico	126	156	151	189	220	259	321	3.2
Western Europe	**1,509**	**1,685**	**1,718**	**1,842**	**1,942**	**2,031**	**2,121**	**0.9**
United Kingdom	234	246	247	264	284	297	311	1.0
France	222	261	265	304	319	336	350	1.2
Germany	373	357	362	381	396	406	417	0.6
Italy	177	201	204	219	233	245	255	0.9
Netherlands	85	99	107	107	114	119	123	0.6
Other Western Europe	418	520	533	567	597	629	665	0.9
Industrialized Asia	**563**	**692**	**699**	**789**	**840**	**891**	**956**	**1.3**
Japan	452	548	552	616	647	675	712	1.1
Australia/New Zealand	111	144	147	173	193	215	244	2.1
Total Industrialized	**4,606**	**5,366**	**5,329**	**6,113**	**6,573**	**7,042**	**7,560**	**1.5**
EE/FSU								
Former Soviet Union	**1,529**	**1,029**	**1,055**	**1,260**	**1,434**	**1,636**	**1,856**	**2.4**
Russia	991	690	711	846	965	1,090	1,218	2.3
Other FSU	538	339	345	414	469	545	638	2.6
Eastern Europe	**393**	**285**	**287**	**340**	**378**	**431**	**469**	**2.1**
Total EE/FSU	**1,923**	**1,314**	**1,342**	**1,600**	**1,812**	**2,067**	**2,325**	**2.3**
Developing Countries								
Developing Asia	**1,322**	**2,029**	**2,143**	**2,942**	**3,607**	**4,361**	**5,162**	**3.7**
China	681	931	1,000	1,461	1,827	2,253	2,673	4.2
India	196	319	322	437	537	661	800	3.9
South Korea	95	199	203	268	310	350	396	2.8
Other Asia	350	580	617	776	934	1,097	1,293	3.1
Middle East	**329**	**511**	**524**	**657**	**768**	**895**	**1,049**	**2.9**
Turkey	50	76	73	99	115	134	156	3.2
Other Middle East	280	435	451	559	653	761	893	2.9
Africa	**235**	**301**	**314**	**395**	**484**	**602**	**717**	**3.5**
Central and South America	**364**	**529**	**527**	**668**	**770**	**902**	**1,079**	**3.0**
Brazil	150	228	221	275	325	381	454	3.0
Other Central/South America	214	302	306	393	446	521	625	3.0
Total Developing	**2,250**	**3,371**	**3,508**	**4,662**	**5,628**	**6,760**	**8,006**	**3.5**
Total World	**8,779**	**10,052**	**10,179**	**12,374**	**14,013**	**15,869**	**17,892**	**2.4**

[a]Includes the 50 States and the District of Columbia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table B1; and System for the Analysis of Global Energy Markets (2004).

Appendix C

Low Economic Growth Case Projections:

- World Energy Consumption
- Gross Domestic Product
- Carbon Dioxide Emissions

Table C1. World Total Primary Energy Consumption by Region, Low Economic Growth Case, 1990-2025
(Quadrillion Btu)

Region/Country	History 1990	History 2000	History 2001	Projections 2010	Projections 2015	Projections 2020	Projections 2025	Average Annual Percent Change, 2001-2025
Industrialized Countries								
North America	**100.6**	**118.7**	**115.6**	**130.1**	**137.7**	**145.5**	**153.6**	**1.2**
United States[a]	84.6	99.3	97.0	108.3	114.3	120.5	126.3	1.1
Canada	11.0	13.2	12.5	14.9	15.7	16.4	17.1	1.3
Mexico	5.0	6.2	6.0	6.9	7.7	8.6	10.2	2.2
Western Europe	**59.9**	**66.8**	**68.2**	**69.1**	**70.4**	**71.8**	**73.3**	**0.3**
United Kingdom	9.3	9.8	9.8	10.1	10.3	10.5	10.7	0.4
France	8.8	10.4	10.5	11.4	11.7	12.1	12.5	0.7
Germany	14.8	14.2	14.4	14.4	14.4	14.5	14.5	0.0
Italy	7.0	8.0	8.1	8.3	8.4	8.6	8.8	0.3
Netherlands	3.4	3.9	4.2	4.3	4.3	4.4	4.5	0.2
Other Western Europe	16.6	20.6	21.1	20.7	21.2	21.7	22.4	0.3
Industrialized Asia	**22.3**	**27.5**	**27.7**	**29.7**	**30.5**	**31.7**	**32.9**	**0.7**
Japan	17.9	21.8	21.9	23.2	23.6	24.4	24.9	0.5
Australia/New Zealand	4.4	5.7	5.8	6.5	6.9	7.3	8.0	1.3
Total Industrialized	**182.8**	**213.0**	**211.5**	**228.9**	**238.6**	**249.0**	**259.8**	**0.9**
EE/FSU								
Former Soviet Union	**60.7**	**40.8**	**41.9**	**43.1**	**45.2**	**47.4**	**49.5**	**0.7**
Russia	39.3	27.4	28.2	29.0	29.0	30.5	31.6	0.5
Other FSU	21.4	13.4	13.7	14.2	16.3	16.9	17.9	1.1
Eastern Europe	**15.6**	**11.3**	**11.4**	**12.1**	**12.7**	**13.4**	**13.4**	**0.7**
Total EE/FSU	**76.3**	**52.2**	**53.3**	**55.3**	**57.9**	**60.8**	**63.0**	**0.7**
Developing Countries								
Developing Asia	**52.5**	**80.5**	**85.0**	**103.3**	**116.3**	**129.7**	**143.3**	**2.2**
China	27.0	37.0	39.7	51.2	59.1	67.4	76.0	2.7
India	7.8	12.7	12.8	15.5	17.9	20.6	23.2	2.5
South Korea	3.8	7.9	8.1	9.5	10.1	10.7	11.2	1.4
Other Asia	13.9	23.0	24.5	27.0	29.2	31.0	32.9	1.2
Middle East	**13.1**	**20.3**	**20.8**	**23.0**	**24.2**	**25.9**	**27.8**	**1.2**
Turkey	2.0	3.0	2.9	3.5	3.7	3.9	4.2	1.5
Other Middle East	11.1	17.3	17.9	19.5	20.5	22.0	23.6	1.2
Africa	**9.3**	**11.9**	**12.4**	**13.3**	**14.3**	**15.4**	**16.6**	**1.2**
Central and South America	**14.4**	**21.0**	**20.9**	**24.1**	**26.2**	**28.6**	**31.5**	**1.7**
Brazil	6.0	9.0	8.8	9.9	11.1	12.2	13.5	1.8
Other Central/South America	8.5	12.0	12.2	14.1	15.1	16.3	18.0	1.6
Total Developing	**89.3**	**133.8**	**139.2**	**163.6**	**181.0**	**199.6**	**219.1**	**1.9**
Total World	**348.4**	**398.9**	**403.9**	**447.8**	**477.5**	**509.4**	**541.9**	**1.2**

[a]Includes the 50 States and the District of Columbia.

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 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table B1; and System for the Analysis of Global Energy Markets (2004).

Table C2. World Total Energy Consumption by Region and Fuel, Low Economic Growth Case, 1990-2025
(Quadrillion Btu)

Region/Country	History			Projections				Average Annual Percent Change, 2001-2025
	1990	2000	2001	2010	2015	2020	2025	
Industrialized Countries								
North America								
Oil	40.4	46.3	45.9	51.2	54.7	57.6	61.3	1.2
Natural Gas	23.1	28.8	27.6	31.4	33.3	35.8	37.9	1.3
Coal	20.7	24.5	23.9	26.8	28.0	29.6	31.4	1.1
Nuclear	6.9	8.7	8.9	9.5	9.7	9.9	9.7	0.3
Other	9.5	10.6	9.4	11.2	11.9	12.5	13.2	1.4
Total	**100.6**	**118.7**	**115.6**	**130.1**	**137.7**	**145.5**	**153.6**	**1.2**
Western Europe								
Oil	25.8	28.5	28.9	29.6	29.9	29.9	30.1	0.2
Natural Gas	9.7	14.9	15.1	16.3	17.8	19.8	22.1	1.6
Coal	12.4	8.4	8.6	7.6	7.0	6.4	6.0	-1.5
Nuclear	7.4	8.8	9.1	8.9	8.8	8.4	7.5	-0.8
Other	4.5	6.0	6.1	6.6	6.9	7.3	7.6	0.9
Total	**59.9**	**66.8**	**68.2**	**69.1**	**70.4**	**71.8**	**73.3**	**0.3**
Industrialized Asia								
Oil	12.1	13.2	13.0	13.6	13.6	14.0	14.3	0.4
Natural Gas	2.5	4.0	4.1	4.5	4.9	5.2	5.8	1.5
Coal	4.2	5.7	5.9	6.3	6.4	6.6	7.0	0.7
Nuclear	2.0	3.0	3.2	3.6	3.9	4.2	4.0	1.0
Other	1.6	1.6	1.6	1.8	1.8	1.8	1.8	0.5
Total	**22.3**	**27.5**	**27.7**	**29.7**	**30.5**	**31.7**	**32.9**	**0.7**
Total Industrialized								
Oil	78.2	88.1	87.8	94.4	98.2	101.6	105.8	0.8
Natural Gas	35.4	47.7	46.8	52.3	56.0	60.8	65.8	1.4
Coal	37.3	38.6	38.5	40.7	41.3	42.6	44.4	0.6
Nuclear	16.3	20.5	21.2	22.0	22.4	22.5	21.2	0.0
Other	15.6	18.2	17.1	19.5	20.6	21.6	22.7	1.2
Total	**182.8**	**213.0**	**211.5**	**228.9**	**238.6**	**249.0**	**259.8**	**0.9**
EE/FSU								
Oil	21.0	10.9	11.0	11.3	12.1	13.0	13.9	1.0
Natural Gas	28.8	23.3	23.8	26.2	28.3	30.9	32.8	1.3
Coal	20.8	12.2	12.4	11.2	10.6	10.1	9.6	-1.1
Nuclear	2.9	3.0	3.1	3.2	3.3	3.0	2.7	-0.6
Other	2.8	3.0	3.2	3.4	3.6	3.8	4.0	0.9
Total	**76.3**	**52.2**	**53.3**	**55.3**	**57.9**	**60.8**	**63.0**	**0.7**
Developing Countries								
Developing Asia								
Oil	16.1	30.2	30.7	38.8	43.5	48.6	53.0	2.3
Natural Gas	3.2	6.9	7.9	9.5	11.0	12.9	15.3	2.8
Coal	29.1	37.1	39.4	45.5	50.2	55.0	60.6	1.8
Nuclear	0.9	1.7	1.8	2.9	3.9	4.6	4.9	4.2
Other	3.2	4.5	5.1	6.6	7.7	8.5	9.5	2.6
Total	**52.5**	**80.5**	**85.0**	**103.3**	**116.3**	**129.7**	**143.3**	**2.2**

See notes at end of table.

Table C2. World Total Energy Consumption by Region and Fuel, Low Economic Growth Case, 1990-2025 (Continued)
(Quadrillion Btu)

Region/Country	History 1990	History 2000	History 2001	Projections 2010	Projections 2015	Projections 2020	Projections 2025	Average Annual Percent Change, 2001-2025
Developing Countries (Continued)								
Middle East								
Oil	8.0	11.0	11.1	12.6	13.3	14.1	14.6	1.2
Natural Gas	3.9	7.7	8.2	8.6	8.8	9.6	10.8	1.1
Coal	0.8	1.1	1.1	1.3	1.3	1.4	1.4	1.1
Nuclear	0.0	0.0	0.0	0.1	0.1	0.2	0.2	—
Other	0.4	0.5	0.4	0.5	0.6	0.7	0.8	2.8
Total	**13.1**	**20.3**	**20.8**	**23.0**	**24.2**	**25.9**	**27.8**	**1.2**
Africa								
Oil	4.2	5.2	5.3	5.7	6.1	6.7	7.0	1.2
Natural Gas	1.5	2.2	2.5	2.6	3.0	3.5	3.9	2.0
Coal	3.0	3.7	3.8	3.9	4.1	4.2	4.4	0.6
Nuclear	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1.2
Other	0.6	0.7	0.8	0.9	0.9	0.9	1.1	1.4
Total	**9.3**	**11.9**	**12.4**	**13.3**	**14.3**	**15.4**	**16.6**	**1.2**
Central and South America								
Oil	7.7	10.6	10.5	11.7	12.7	13.8	15.1	1.5
Natural Gas	2.2	3.6	3.8	4.6	5.5	6.4	7.7	3.0
Coal	0.6	0.9	0.8	1.1	1.1	1.2	1.3	2.0
Nuclear	0.1	0.1	0.2	0.2	0.2	0.2	0.2	-1.0
Other	3.9	5.9	5.6	6.4	6.7	7.0	7.3	1.1
Total	**14.4**	**21.0**	**20.9**	**24.1**	**26.2**	**28.6**	**31.5**	**1.7**
Total Developing Countries								
Oil	35.9	56.9	57.6	68.8	75.6	83.1	89.7	1.9
Natural Gas	10.8	20.4	22.4	25.4	28.4	32.5	37.7	2.2
Coal	33.5	42.8	45.1	51.7	56.7	61.8	67.7	1.7
Nuclear	1.1	2.0	2.2	3.3	4.4	5.1	5.4	3.9
Other	8.0	11.6	11.8	14.4	15.9	17.2	18.6	1.9
Total	**89.3**	**133.8**	**139.2**	**163.6**	**181.0**	**199.6**	**219.1**	**1.9**
Total World								
Oil	135.1	155.9	156.5	174.5	185.9	197.7	209.3	1.2
Natural Gas	75.0	91.4	93.1	103.8	112.7	124.2	136.4	1.6
Coal	91.6	93.6	95.9	103.6	108.6	114.5	121.6	1.0
Nuclear	20.3	25.5	26.4	28.5	30.1	30.6	29.4	0.4
Other	26.4	32.8	32.2	37.4	40.2	42.5	45.2	1.4
Total	**348.4**	**398.9**	**403.9**	**447.8**	**477.5**	**509.4**	**541.9**	**1.2**

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 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table B1; and System for the Analysis of Global Energy Markets (2004).

Table C3. World Gross Domestic Product (GDP) by Region, Low Economic Growth Case, 1990-2025
(Billion 1997 Dollars)

Region/Country	History			Projections				Average Annual Percent Change, 2001-2025
	1990	2000	2001	2010	2015	2020	2025	
Industrialized Countries								
North America	**7,723**	**10,573**	**10,609**	**13,454**	**15,181**	**16,962**	**18,861**	**2.4**
United States[a]	6,839	9,370	9,394	11,955	13,474	15,008	16,597	2.4
Canada	553	737	751	931	1,038	1,147	1,259	2.2
Mexico	331	465	464	568	669	807	1,006	3.3
Western Europe	**7,635**	**9,356**	**9,513**	**10,765**	**11,684**	**12,677**	**13,731**	**1.5**
United Kingdom	1,153	1,461	1,492	1,764	1,952	2,148	2,358	1.9
France	1,300	1,568	1,601	1,816	1,973	2,151	2,350	1.6
Germany	1,917	2,261	2,284	2,472	2,624	2,784	2,946	1.1
Italy	1,063	1,248	1,269	1,414	1,520	1,640	1,761	1.4
Netherlands	317	423	428	470	508	552	601	1.4
Other Western Europe	1,885	2,396	2,440	2,828	3,106	3,402	3,716	1.8
Industrialized Asia	**4,189**	**4,925**	**4,955**	**5,506**	**5,917**	**6,331**	**6,756**	**1.3**
Japan	3,808	4,395	4,411	4,826	5,146	5,462	5,784	1.1
Australia/New Zealand	381	530	543	680	772	869	972	2.5
Total Industrialized	**19,546**	**24,854**	**25,077**	**29,725**	**32,782**	**35,970**	**39,348**	**1.9**
EE/FSU								
Former Soviet Union	**929**	**597**	**632**	**857**	**981**	**1,102**	**1,213**	**2.8**
Russia	668	449	471	610	686	759	822	2.3
Other FSU	261	148	161	246	295	343	391	3.8
Eastern Europe	**353**	**379**	**389**	**500**	**578**	**668**	**763**	**2.8**
Total EE/FSU	**1,282**	**976**	**1,022**	**1,357**	**1,560**	**1,770**	**1,976**	**2.8**
Developing Countries								
Developing Asia	**1,766**	**3,403**	**3,536**	**5,310**	**6,523**	**7,807**	**9,213**	**4.1**
China	428	1,120	1,202	2,044	2,608	3,235	3,958	5.1
India	290	492	520	766	944	1,154	1,399	4.2
South Korea	299	544	562	820	961	1,074	1,178	3.1
Other Asia	749	1,246	1,253	1,681	2,010	2,345	2,678	3.2
Middle East	**409**	**594**	**584**	**720**	**825**	**937**	**1,053**	**2.5**
Turkey	139	198	183	230	267	309	351	2.8
Other Middle East	270	396	400	490	557	628	702	2.4
Africa	**488**	**606**	**626**	**824**	**958**	**1,104**	**1,260**	**3.0**
Central and South America	**1,105**	**1,503**	**1,510**	**1,786**	**2,092**	**2,444**	**2,866**	**2.7**
Brazil	655	851	863	1,032	1,208	1,406	1,638	2.7
Other Central/South America	450	652	647	753	883	1,039	1,228	2.7
Total Developing	**3,767**	**6,106**	**6,256**	**8,640**	**10,397**	**12,292**	**14,392**	**3.5**
Total World	**24,596**	**31,937**	**32,354**	**39,722**	**44,739**	**50,031**	**55,717**	**2.3**

[a]Includes the 50 States and the District of Columbia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding.

Sources: Global Insight, Inc., *World Economic Outlook*, Vol. 1 (Lexington, MA, Third Quarter 2003), and Energy Information Administration, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table B20.

Table C4. World Oil Consumption by Region, Low Economic Growth Case, 1990-2025
(Million Barrels per Day)

Region/Country	History			Projections				Average Annual Percent Change, 2001-2025
	1990	2000	2001	2010	2015	2020	2025	
Industrialized Countries								
North America	**20.4**	**23.8**	**23.5**	**26.3**	**28.1**	**29.5**	**31.4**	**1.2**
United States[a]	17.0	19.7	19.6	21.8	23.3	24.5	25.9	1.2
Canada	1.7	2.1	1.9	2.2	2.3	2.5	2.6	1.3
Mexico	1.7	2.0	1.9	2.2	2.4	2.5	3.0	1.8
Western Europe	**12.5**	**13.8**	**14.0**	**14.3**	**14.4**	**14.5**	**14.6**	**0.2**
United Kingdom	1.8	1.7	1.7	1.8	1.8	1.9	2.0	0.7
France	1.8	2.0	2.0	2.0	2.0	2.0	2.0	-0.1
Germany	2.7	2.8	2.8	2.9	2.9	3.0	3.0	0.3
Italy	1.9	1.9	1.9	2.0	2.0	2.0	2.0	0.3
Netherlands	0.7	0.9	0.9	0.9	0.9	0.9	0.9	0.0
Other Western Europe	3.6	4.6	4.7	4.7	4.8	4.7	4.6	0.0
Industrialized Asia	**6.0**	**6.5**	**6.4**	**6.7**	**6.8**	**6.9**	**7.1**	**0.4**
Japan	5.1	5.5	5.4	5.5	5.5	5.5	5.6	0.1
Australia/New Zealand	0.8	1.0	1.0	1.2	1.3	1.4	1.5	1.7
Total Industrialized	**38.8**	**44.1**	**43.9**	**47.3**	**49.3**	**50.9**	**53.1**	**0.8**
EE/FSU								
Former Soviet Union	**8.4**	**3.8**	**3.9**	**4.0**	**4.3**	**4.6**	**4.9**	**1.0**
Russia	5.4	2.6	2.6	2.7	2.9	3.1	3.3	1.0
Other FSU	3.0	1.2	1.3	1.3	1.4	1.6	1.6	1.0
Eastern Europe	**1.6**	**1.4**	**1.4**	**1.4**	**1.5**	**1.6**	**1.7**	**0.9**
Total EE/FSU	**10.0**	**5.2**	**5.3**	**5.4**	**5.8**	**6.3**	**6.7**	**1.0**
Developing Countries								
Developing Asia	**7.6**	**14.5**	**14.8**	**18.7**	**21.0**	**23.4**	**25.5**	**2.3**
China	2.3	4.8	5.0	7.2	8.3	9.5	10.6	3.2
India	1.2	2.1	2.1	2.6	3.1	3.8	4.4	3.0
South Korea	1.0	2.1	2.1	2.3	2.4	2.4	2.4	0.5
Other Asia	3.1	5.5	5.5	6.6	7.2	7.7	8.2	1.6
Middle East	**3.8**	**5.3**	**5.4**	**6.1**	**6.4**	**6.8**	**7.1**	**1.2**
Turkey	0.5	0.7	0.6	0.7	0.8	0.8	0.9	1.4
Other Middle East	3.4	4.7	4.7	5.4	5.7	6.0	6.2	1.1
Africa	**2.1**	**2.5**	**2.6**	**2.8**	**3.0**	**3.2**	**3.4**	**1.2**
Central and South America	**3.7**	**5.2**	**5.2**	**5.8**	**6.2**	**6.8**	**7.4**	**1.5**
Brazil	1.5	2.2	2.2	2.4	2.5	2.8	3.0	1.4
Other Central/South America	2.3	3.0	3.0	3.4	3.7	4.0	4.4	1.6
Total Developing	**17.3**	**27.6**	**27.9**	**33.3**	**36.6**	**40.2**	**43.4**	**1.9**
Total World	**66.1**	**76.9**	**77.1**	**86.1**	**91.7**	**97.4**	**103.2**	**1.2**

[a]Includes the 50 States and the District of Columbia.

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 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table B21; and System for the Analysis of Global Energy Markets (2004).

Table C5. World Natural Gas Consumption by Region, Low Economic Growth Case, 1990-2025
(Trillion Cubic Feet)

Region/Country	History			Projections				Average Annual Percent Change, 2001-2025
	1990	2000	2001	2010	2015	2020	2025	
Industrialized Countries								
North America	**22.5**	**28.1**	**26.9**	**30.6**	**32.5**	**34.9**	**36.9**	**1.3**
United States[a]	19.2	23.5	22.6	25.1	26.4	28.0	29.1	1.1
Canada	2.4	3.3	2.9	3.9	4.2	4.4	4.7	2.0
Mexico	0.9	1.4	1.4	1.6	1.9	2.5	3.1	3.5
Western Europe	**10.1**	**14.6**	**14.8**	**16.0**	**17.4**	**19.3**	**21.6**	**1.6**
United Kingdom	2.1	3.4	3.3	3.7	4.2	4.5	4.8	1.6
France	1.0	1.4	1.5	1.5	1.6	1.6	1.6	0.4
Germany	2.7	3.2	3.3	3.5	3.9	4.9	5.1	1.8
Italy	1.7	2.5	2.5	2.7	2.9	3.1	3.2	1.0
Netherlands	1.5	1.7	1.8	1.7	1.9	2.0	2.0	0.6
Other Western Europe	1.2	2.3	2.4	2.8	2.9	3.2	4.9	2.9
Industrialized Asia	**2.6**	**3.8**	**3.9**	**4.3**	**4.6**	**5.0**	**5.5**	**1.5**
Japan	1.9	2.8	2.8	3.2	3.4	3.5	3.9	1.3
Australia/New Zealand	0.8	1.0	1.1	1.1	1.3	1.4	1.6	1.8
Total Industrialized	**35.2**	**46.4**	**45.6**	**50.9**	**54.5**	**59.2**	**64.1**	**1.4**
EE/FSU								
Former Soviet Union	**25.0**	**20.5**	**20.8**	**22.1**	**23.7**	**25.5**	**27.4**	**1.2**
Russia	17.3	14.1	14.4	14.9	15.9	16.8	17.7	0.9
Other FSU	7.7	6.4	6.4	7.2	7.8	8.6	9.7	1.7
Eastern Europe	**3.1**	**2.4**	**2.7**	**3.7**	**4.2**	**5.0**	**5.0**	**2.6**
Total EE/FSU	**28.1**	**23.0**	**23.5**	**25.8**	**27.9**	**30.5**	**32.4**	**1.3**
Developing Countries								
Developing Asia	**3.0**	**6.6**	**7.5**	**8.9**	**10.4**	**12.1**	**14.3**	**2.7**
China	0.5	1.0	1.0	1.8	2.3	3.1	4.1	6.1
India	0.4	0.8	0.8	1.2	1.4	1.7	2.0	3.9
South Korea	0.1	0.7	0.7	1.0	1.1	1.3	1.5	2.9
Other Asia	2.0	4.2	4.9	5.0	5.5	6.0	6.6	1.3
Middle East	**3.7**	**7.3**	**7.9**	**8.2**	**8.4**	**9.2**	**10.3**	**1.1**
Turkey	0.1	0.5	0.6	0.7	0.8	0.9	1.0	2.2
Other Middle East	3.6	6.8	7.3	7.5	7.6	8.3	9.3	1.0
Africa	**1.4**	**2.0**	**2.3**	**2.5**	**2.8**	**3.2**	**3.7**	**2.0**
Central and South America	**2.0**	**3.3**	**3.5**	**4.3**	**5.1**	**5.9**	**7.1**	**3.0**
Brazil	0.1	0.3	0.3	0.9	1.5	1.8	2.2	8.0
Other Central/South America	1.9	3.0	3.2	3.4	3.6	4.2	4.9	1.9
Total Developing	**10.1**	**19.3**	**21.2**	**23.9**	**26.7**	**30.4**	**35.3**	**2.1**
Total World	**73.4**	**88.7**	**90.3**	**100.6**	**109.1**	**120.1**	**131.7**	**1.6**

[a]Includes the 50 States and the District of Columbia.

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 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table B13; and System for the Analysis of Global Energy Markets (2004).

Table C6. World Coal Consumption by Region, Low Economic Growth Case, 1990-2025
(Million Short Tons)

Region/Country	History 1990	History 2000	History 2001	Projections 2010	Projections 2015	Projections 2020	Projections 2025	Average Annual Percent Change, 2001-2025
Industrialized Countries								
North America	**971**	**1,168**	**1,148**	**1,299**	**1,366**	**1,449**	**1,545**	**1.2**
United States[a]	903	1,084	1,060	1,205	1,269	1,349	1,441	1.3
Canada	59	69	73	74	77	77	78	0.3
Mexico	9	15	15	19	21	23	25	2.3
Western Europe	**894**	**559**	**574**	**508**	**463**	**425**	**397**	**-1.5**
United Kingdom	119	64	71	65	59	51	42	-2.1
France	35	25	21	12	11	11	9	-3.3
Germany	528	264	265	255	227	210	199	-1.2
Italy	25	20	22	20	19	18	17	-1.2
Netherlands	15	14	23	17	15	14	13	-2.3
Other Western Europe	172	172	172	138	131	122	116	-1.6
Industrialized Asia	**231**	**303**	**312**	**331**	**337**	**348**	**371**	**0.7**
Japan	125	160	166	175	179	184	189	0.6
Australia/New Zealand	106	143	147	156	158	163	182	0.9
Total Industrialized	**2,095**	**2,029**	**2,034**	**2,138**	**2,167**	**2,222**	**2,313**	**0.5**
EE/FSU								
Former Soviet Union	**848**	**421**	**446**	**408**	**390**	**382**	**364**	**-0.8**
Russia	497	267	284	276	268	262	249	-0.5
Other FSU	352	154	162	132	122	120	116	-1.4
Eastern Europe	**528**	**390**	**382**	**341**	**314**	**288**	**268**	**-1.5**
Total EE/FSU	**1,376**	**811**	**828**	**748**	**705**	**670**	**632**	**-1.1**
Developing Countries								
Developing Asia	**1,590**	**1,959**	**2,084**	**2,411**	**2,664**	**2,930**	**3,232**	**1.8**
China	1,124	1,282	1,383	1,634	1,841	2,065	2,315	2.2
India	242	359	360	412	453	493	540	1.7
South Korea	49	72	76	99	101	102	104	1.3
Other Asia	175	246	265	266	268	270	273	0.1
Middle East	**66**	**94**	**95**	**110**	**118**	**120**	**123**	**1.1**
Turkey	60	80	81	92	101	102	106	1.1
Other Middle East	6	14	14	18	18	18	17	1.0
Africa	**152**	**187**	**191**	**196**	**204**	**211**	**220**	**0.6**
Central and South America	**27**	**34**	**32**	**42**	**43**	**47**	**51**	**2.0**
Brazil	17	21	21	29	29	31	34	2.1
Other Central/South America	10	13	11	13	14	16	17	1.9
Total Developing	**1,835**	**2,275**	**2,401**	**2,759**	**3,030**	**3,307**	**3,626**	**1.7**
Total World	**5,307**	**5,115**	**5,263**	**5,645**	**5,901**	**6,199**	**6,571**	**0.9**

[a]Includes the 50 States and the District of Columbia.

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 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table B16; and System for the Analysis of Global Energy Markets (2004).

Table C7. World Nuclear Energy Consumption by Region, Low Economic Growth Case, 1990-2025
(Billion Kilowatthours)

Region/Country	History			Projections				Average Annual Percent Change, 2001-2025
	1990	2000	2001	2010	2015	2020	2025	
Industrialized Countries								
North America	**649**	**830**	**850**	**905**	**925**	**938**	**919**	**0.3**
United States[a]	577	754	769	794	812	816	816	0.3
Canada	69	69	73	102	104	111	92	1.0
Mexico	3	8	8	9	9	10	11	1.1
Western Europe	**703**	**845**	**870**	**850**	**844**	**806**	**718**	**-0.8**
United Kingdom	59	82	86	65	49	45	26	-4.8
France	298	394	401	420	450	490	520	1.1
Germany	145	161	163	129	100	14	0	-100.0
Italy	0	0	0	0	0	0	0	—
Netherlands	3	4	4	4	4	0	0	-100.0
Other Western Europe	198	204	217	233	242	257	172	-1.0
Industrialized Asia	**192**	**294**	**309**	**353**	**377**	**409**	**395**	**1.0**
Japan	192	294	309	353	377	409	395	1.0
Australia/New Zealand	0	0	0	0	0	0	0	—
Total Industrialized	**1,544**	**1,969**	**2,029**	**2,108**	**2,146**	**2,152**	**2,031**	**0.0**
EE/FSU								
Former Soviet Union	**201**	**204**	**210**	**220**	**221**	**192**	**164**	**-1.0**
Russia	115	122	125	131	145	121	94	-1.2
Other FSU	86	81	85	89	77	71	70	-0.8
Eastern Europe	**54**	**67**	**72**	**71**	**75**	**79**	**83**	**0.6**
Total EE/FSU	**256**	**270**	**282**	**291**	**296**	**271**	**247**	**-0.6**
Developing Countries								
Developing Asia	**88**	**171**	**178**	**278**	**381**	**447**	**473**	**4.2**
China	0	16	17	62	122	134	146	9.5
India	6	14	18	39	50	63	66	5.5
South Korea	50	104	107	133	161	198	208	2.8
Other Asia	32	37	36	44	48	52	53	1.6
Middle East	**0**	**0**	**0**	**5**	**13**	**14**	**21**	**—**
Turkey	0	0	0	0	0	0	0	—
Other Middle East	0	0	0	5	13	14	21	—
Africa	**8**	**13**	**11**	**13**	**14**	**14**	**14**	**1.2**
Central and South America	**9**	**11**	**21**	**19**	**19**	**16**	**16**	**-1.0**
Brazil	2	5	14	13	13	13	13	-0.4
Other Central/South America	7	6	7	6	6	3	3	-2.7
Total Developing	**105**	**195**	**209**	**316**	**427**	**492**	**524**	**3.9**
Total World	**1,905**	**2,434**	**2,521**	**2,715**	**2,869**	**2,914**	**2,803**	**0.4**

[a]Includes the 50 States and the District of Columbia.

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 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table B8; and System for the Analysis of Global Energy Markets (2004).

Table C8. World Consumption of Hydroelectricity and Other Renewable Energy by Region, Low Economic Growth Case, 1990-2025
(Quadrillion Btu)

Region/Country	History			Projections				Average Annual Percent Change, 2001-2025
	1990	2000	2001	2010	2015	2020	2025	
Industrialized Countries								
North America	**9.5**	**10.6**	**9.4**	**11.2**	**11.9**	**12.5**	**13.2**	**1.4**
United States[a]	6.0	6.4	5.5	7.1	7.6	8.0	8.4	1.8
Canada	3.1	3.8	3.5	3.7	3.8	4.0	4.3	0.8
Mexico	0.3	0.5	0.4	0.5	0.5	0.5	0.5	1.0
Western Europe	**4.5**	**6.0**	**6.1**	**6.6**	**6.9**	**7.3**	**7.6**	**0.9**
United Kingdom	0.1	0.1	0.1	0.2	0.2	0.2	0.3	5.3
France	0.6	0.7	0.8	0.9	0.8	0.9	0.9	0.6
Germany	0.3	0.4	0.5	0.5	0.6	0.6	0.6	1.0
Italy	0.4	0.6	0.6	0.8	0.8	0.8	0.9	1.5
Netherlands	0.0	0.1	0.1	0.2	0.2	0.2	0.2	6.0
Other Western Europe	3.2	4.1	4.1	4.0	4.3	4.6	4.7	0.6
Industrialized Asia	**1.6**	**1.6**	**1.6**	**1.8**	**1.8**	**1.8**	**1.8**	**0.5**
Japan	1.1	1.1	1.1	1.2	1.2	1.2	1.3	0.6
Australia/New Zealand	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total Industrialized	**15.6**	**18.2**	**17.1**	**19.5**	**20.6**	**21.6**	**22.7**	**1.2**
EE/FSU								
Former Soviet Union	**2.4**	**2.3**	**2.5**	**2.7**	**2.9**	**3.0**	**3.1**	**0.9**
Russia	1.8	1.7	1.8	1.9	2.0	2.1	2.2	0.7
Other FSU	0.6	0.7	0.7	0.8	0.9	0.9	1.0	1.4
Eastern Europe	**0.4**	**0.6**	**0.6**	**0.7**	**0.8**	**0.8**	**0.8**	**0.9**
Total EE/FSU	**2.8**	**3.0**	**3.2**	**3.4**	**3.6**	**3.8**	**4.0**	**0.9**
Developing Countries								
Developing Asia	**3.2**	**4.5**	**5.1**	**6.6**	**7.7**	**8.5**	**9.5**	**2.6**
China	1.3	2.3	2.8	3.8	4.4	5.0	5.6	3.0
India	0.7	0.8	0.8	1.0	1.2	1.3	1.5	2.6
South Korea	0.0	0.0	0.0	0.1	0.1	0.1	0.1	5.5
Other Asia	1.1	1.4	1.5	1.7	2.0	2.1	2.3	1.9
Middle East	**0.4**	**0.5**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**2.8**
Turkey	0.2	0.3	0.3	0.3	0.3	0.4	0.5	2.5
Other Middle East	0.1	0.1	0.1	0.2	0.2	0.3	0.3	3.2
Africa	**0.6**	**0.7**	**0.8**	**0.9**	**0.9**	**0.9**	**1.1**	**1.4**
Central and South America	**3.9**	**5.9**	**5.6**	**6.4**	**6.7**	**7.0**	**7.3**	**1.1**
Brazil	2.2	3.3	2.9	3.4	3.5	3.8	4.1	1.4
Other Central/South America	1.7	2.6	2.7	3.1	3.2	3.2	3.2	0.7
Total Developing	**8.0**	**11.6**	**11.8**	**14.4**	**15.9**	**17.2**	**18.6**	**1.9**
Total World	**26.4**	**32.8**	**32.2**	**37.4**	**40.2**	**42.5**	**45.2**	**1.4**

[a]Includes the 50 States and the District of Columbia.

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 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table B1; and System for the Analysis of Global Energy Markets (2004).

Table C9. World Carbon Dioxide Emissions by Region, Low Economic Growth Case, 1990-2025
(Million Metric Tons Carbon Dioxide)

Region/Country	History			Projections				Average Annual Percent Change, 2001-2025
	1990	2000	2001	2010	2015	2020	2025	
Industrialized Countries								
North America	**5,769**	**6,731**	**6,613**	**7,444**	**7,897**	**8,374**	**8,908**	**1.2**
United States[a]	4,989	5,787	5,692	6,368	6,739	7,136	7,538	1.2
Canada	473	581	569	667	704	732	770	1.3
Mexico	308	364	352	409	453	505	600	2.2
Western Europe	**3,412**	**3,442**	**3,465**	**3,478**	**3,505**	**3,558**	**3,655**	**0.2**
United Kingdom	600	553	563	585	605	614	626	0.4
France	374	401	396	381	380	374	377	-0.2
Germany	995	828	819	824	822	862	863	0.2
Italy	415	443	445	470	478	484	491	0.4
Netherlands	211	228	248	225	229	231	232	-0.3
Other Western Europe	816	989	994	993	991	994	1,066	0.3
Industrialized Asia	**1,280**	**1,526**	**1,556**	**1,651**	**1,684**	**1,744**	**1,831**	**0.7**
Japan	987	1,138	1,158	1,208	1,219	1,248	1,285	0.4
Australia/New Zealand	294	387	398	443	465	496	547	1.3
Total Industrialized	**10,462**	**11,699**	**11,634**	**12,573**	**13,086**	**13,677**	**14,395**	**0.9**
EE/FSU								
Former Soviet Union	**3,798**	**2,338**	**2,399**	**2,419**	**2,521**	**2,653**	**2,769**	**0.6**
Russia	2,405	1,570	1,614	1,636	1,705	1,778	1,829	0.5
Other FSU	1,393	767	785	782	817	875	940	0.8
Eastern Europe	**1,104**	**756**	**748**	**760**	**770**	**796**	**788**	**0.2**
Total EE/FSU	**4,902**	**3,094**	**3,148**	**3,179**	**3,291**	**3,449**	**3,556**	**0.5**
Developing Countries								
Developing Asia	**3,994**	**5,709**	**6,012**	**7,166**	**7,980**	**8,849**	**9,768**	**2.0**
China	2,262	2,861	3,050	3,816	4,350	4,943	5,570	2.5
India	561	914	917	1,087	1,235	1,401	1,572	2.3
South Korea	234	425	443	526	555	574	596	1.2
Other Asia	937	1,509	1,602	1,737	1,839	1,931	2,031	1.0
Middle East	**846**	**1,262**	**1,299**	**1,438**	**1,509**	**1,608**	**1,707**	**1.1**
Turkey	129	184	184	239	257	267	284	1.8
Other Middle East	717	1,078	1,115	1,199	1,252	1,340	1,423	1.0
Africa	**656**	**811**	**843**	**893**	**956**	**1,028**	**1,094**	**1.1**
Central and South America	**703**	**961**	**964**	**1,111**	**1,219**	**1,350**	**1,512**	**1.9**
Brazil	250	343	347	417	471	523	585	2.2
Other Central/South America	453	618	617	694	747	827	926	1.7
Total Developing	**6,200**	**8,744**	**9,118**	**10,608**	**11,663**	**12,834**	**14,081**	**1.8**
Total World	**21,563**	**23,536**	**23,899**	**26,360**	**28,040**	**29,960**	**32,032**	**1.2**

[a]Includes the 50 States and the District of Columbia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. The U.S. numbers include carbon dioxide emissions attributable to renewable energy sources.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table B19; and System for the Analysis of Global Energy Markets (2004).

Table C10. World Carbon Dioxide Emissions from Oil Use by Region, Low Economic Growth Case, 1990-2025
(Million Metric Tons Carbon Dioxide)

Region/Country	History			Projections				Average Annual Percent Change, 2001-2025
	1990	2000	2001	2010	2015	2020	2025	
Industrialized Countries								
North America	**2,626**	**2,935**	**2,967**	**3,285**	**3,525**	**3,716**	**3,967**	**1.2**
United States[a]	2,165	2,416	2,458	2,697	2,898	3,056	3,233	1.1
Canada	222	258	258	301	317	333	351	1.3
Mexico	239	261	251	286	310	328	384	1.8
Western Europe	**1,739**	**1,853**	**1,845**	**1,892**	**1,906**	**1,909**	**1,922**	**0.2**
United Kingdom	242	231	231	245	248	255	272	0.7
France	245	267	267	268	267	262	263	-0.1
Germany	376	357	348	356	363	374	375	0.3
Italy	270	261	261	277	277	275	280	0.3
Netherlands	99	98	98	96	97	97	98	0.0
Other Western Europe	507	639	639	650	654	647	635	0.0
Industrialized Asia	**768**	**802**	**802**	**842**	**846**	**870**	**889**	**0.4**
Japan	655	667	668	681	672	682	688	0.1
Australia/New Zealand	113	134	134	161	174	188	201	1.7
Total Industrialized	**5,133**	**5,589**	**5,613**	**6,019**	**6,277**	**6,495**	**6,779**	**0.8**
EE/FSU								
Former Soviet Union	**1,224**	**547**	**557**	**570**	**614**	**665**	**705**	**1.0**
Russia	783	366	369	377	406	440	466	1.0
Other FSU	441	181	189	193	208	225	239	1.0
Eastern Europe	**243**	**189**	**189**	**192**	**202**	**218**	**233**	**0.9**
Total EE/FSU	**1,468**	**736**	**746**	**762**	**816**	**883**	**938**	**1.0**
Developing Countries								
Developing Asia	**1,116**	**1,912**	**1,953**	**2,465**	**2,766**	**3,086**	**3,366**	**2.3**
China	345	619	642	926	1,069	1,231	1,364	3.2
India	165	279	279	343	412	495	571	3.0
South Korea	138	239	245	263	269	271	276	0.5
Other Asia	468	775	787	933	1,016	1,088	1,155	1.6
Middle East	**568**	**753**	**764**	**869**	**917**	**973**	**1,008**	**1.2**
Turkey	64	81	81	98	103	108	112	1.4
Other Middle East	504	672	682	771	814	866	896	1.1
Africa	**304**	**356**	**366**	**395**	**424**	**459**	**486**	**1.2**
Central and South America	**533**	**694**	**691**	**769**	**830**	**903**	**989**	**1.5**
Brazil	210	276	280	301	325	355	388	1.4
Other Central/South America	323	418	411	468	505	548	600	1.6
Total Developing	**2,521**	**3,716**	**3,774**	**4,498**	**4,937**	**5,421**	**5,849**	**1.8**
Total World	**9,121**	**10,041**	**10,134**	**11,278**	**12,030**	**12,798**	**13,566**	**1.2**

[a]Includes the 50 States and the District of Columbia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table B19; and System for the Analysis of Global Energy Markets (2004).

Table C11. World Carbon Dioxide Emissions from Natural Gas Use by Region, Low Economic Growth Case, 1990-2025
(Million Metric Tons Carbon Dioxide)

Region/Country	History			Projections				Average Annual Percent Change, 2001-2025
	1990	2000	2001	2010	2015	2020	2025	
Industrialized Countries								
North America	**1,207**	**1,503**	**1,421**	**1,653**	**1,753**	**1,885**	**1,996**	**1.4**
United States[a]	1,025	1,249	1,189	1,355	1,421	1,510	1,569	1.2
Canada	127	177	156	207	224	236	252	2.0
Mexico	54	77	77	91	108	139	174	3.5
Western Europe	**514**	**786**	**799**	**863**	**938**	**1,044**	**1,167**	**1.6**
United Kingdom	110	188	183	205	232	252	266	1.6
France	57	81	85	86	90	90	94	1.8
Germany	116	165	173	182	203	253	265	1.8
Italy	91	135	136	148	158	170	173	1.0
Netherlands	72	81	83	81	89	95	96	0.6
Other Western Europe	67	134	139	161	167	185	272	2.8
Industrialized Asia	**133**	**209**	**216**	**238**	**257**	**275**	**306**	**1.5**
Japan	89	152	157	175	186	195	216	1.3
Australia/New Zealand	44	57	59	63	71	80	91	1.8
Total Industrialized	**1,853**	**2,497**	**2,436**	**2,753**	**2,949**	**3,205**	**3,469**	**1.5**
EE/FSU								
Former Soviet Union	**1,352**	**1,103**	**1,119**	**1,188**	**1,274**	**1,369**	**1,473**	**1.2**
Russia	928	753	768	795	847	897	944	0.9
Other FSU	424	351	351	393	427	472	529	1.7
Eastern Europe	**167**	**127**	**139**	**194**	**222**	**262**	**260**	**2.6**
Total EE/FSU	**1,519**	**1,231**	**1,258**	**1,382**	**1,495**	**1,631**	**1,733**	**1.3**
Developing Countries								
Developing Asia	**167**	**366**	**419**	**501**	**583**	**682**	**809**	**2.8**
China	31	59	66	123	163	215	285	6.3
India	24	43	44	64	76	92	110	3.9
South Korea	6	40	44	63	79	95	107	3.8
Other Asia	106	225	266	252	265	281	307	0.6
Middle East	**205**	**406**	**435**	**453**	**466**	**507**	**568**	**1.1**
Turkey	7	29	31	61	65	70	78	3.9
Other Middle East	199	377	404	392	401	437	490	0.8
Africa	**80**	**116**	**130**	**140**	**160**	**184**	**209**	**2.0**
Central and South America	**116**	**188**	**200**	**245**	**291**	**340**	**405**	**3.0**
Brazil	6	18	19	49	80	97	118	8.0
Other Central/South America	110	170	182	196	211	243	287	1.9
Total Developing	**569**	**1,077**	**1,184**	**1,339**	**1,499**	**1,714**	**1,991**	**2.2**
Total World	**3,941**	**4,805**	**4,878**	**5,474**	**5,944**	**6,549**	**7,192**	**1.6**

[a]Includes the 50 States and the District of Columbia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table B19; and System for the Analysis of Global Energy Markets (2004).

Table C12. World Carbon Dioxide Emissions from Coal Use by Region, Low Economic Growth Case, 1990-2025
(Million Metric Tons Carbon Dioxide)

Region/Country	History			Projections				Average Annual Percent Change, 2001-2025
	1990	2000	2001	2010	2015	2020	2025	
Industrialized Countries								
North America	**1,933**	**2,293**	**2,222**	**2,506**	**2,619**	**2,772**	**2,945**	**1.2**
United States[a]	1,794	2,122	2,042	2,316	2,420	2,570	2,736	1.2
Canada	123	146	155	158	163	163	167	0.3
Mexico	15	25	25	32	35	39	43	2.3
Western Europe	**1,159**	**804**	**821**	**723**	**660**	**606**	**566**	**-1.5**
United Kingdom	248	134	149	136	125	106	89	-2.1
France	72	52	44	26	24	23	20	-3.3
Germany	503	306	298	287	255	236	224	-1.2
Italy	54	48	49	45	43	39	37	-1.2
Netherlands	40	49	67	48	43	40	38	-2.3
Other Western Europe	242	216	215	182	171	161	159	-1.3
Industrialized Asia	**380**	**515**	**539**	**571**	**581**	**599**	**636**	**0.7**
Japan	243	319	334	352	361	371	381	0.6
Australia/New Zealand	137	196	205	218	220	228	254	0.9
Total Industrialized	**3,472**	**3,613**	**3,581**	**3,800**	**3,860**	**3,977**	**4,147**	**0.6**
EE/FSU								
Former Soviet Union	**1,222**	**687**	**723**	**661**	**633**	**619**	**591**	**-0.8**
Russia	694	452	478	464	452	441	419	-0.5
Other FSU	528	236	245	197	181	178	172	-1.5
Eastern Europe	**694**	**440**	**420**	**374**	**346**	**317**	**295**	**-1.5**
Total EE/FSU	**1,915**	**1,127**	**1,143**	**1,036**	**979**	**936**	**885**	**-1.1**
Developing Countries								
Developing Asia	**2,710**	**3,431**	**3,639**	**4,201**	**4,631**	**5,081**	**5,593**	**1.8**
China	1,886	2,183	2,342	2,767	3,118	3,497	3,921	2.2
India	371	592	594	680	748	813	890	1.7
South Korea	90	146	155	201	207	208	213	1.3
Other Asia	363	509	549	553	558	562	569	0.2
Middle East	**73**	**103**	**100**	**117**	**125**	**127**	**130**	**1.1**
Turkey	59	74	71	81	88	90	93	1.1
Other Middle East	14	29	29	36	37	37	37	1.0
Africa	**272**	**339**	**347**	**358**	**372**	**385**	**400**	**0.6**
Central and South America	**54**	**78**	**73**	**96**	**99**	**107**	**118**	**2.0**
Brazil	34	49	48	66	67	71	79	2.1
Other Central/South America	20	30	25	30	32	36	39	1.9
Total Developing	**3,110**	**3,951**	**4,160**	**4,771**	**5,227**	**5,699**	**6,241**	**1.7**
Total World	**8,497**	**8,691**	**8,884**	**9,607**	**10,066**	**10,612**	**11,274**	**1.0**

[a]Includes the 50 States and the District of Columbia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table B19; and System for the Analysis of Global Energy Markets (2004).

Table C13. World Total Energy Consumption in Oil-Equivalent Units by Region, Low Economic Growth Case, 1990-2025
(Million Tons Oil Equivalent)

Region/Country	History			Projections				Average Annual Percent Change, 2001-2025
	1990	2000	2001	2010	2015	2020	2025	
Industrialized Countries								
North America	**2,534**	**2,990**	**2,912**	**3,279**	**3,470**	**3,667**	**3,870**	**1.2**
United States[a]	2,131	2,503	2,446	2,730	2,882	3,037	3,184	1.1
Canada	278	331	315	375	395	414	430	1.3
Mexico	126	156	151	175	193	216	256	2.2
Western Europe	**1,509**	**1,685**	**1,718**	**1,741**	**1,773**	**1,809**	**1,848**	**0.3**
United Kingdom	234	246	247	254	259	264	269	0.4
France	222	261	265	286	295	305	314	0.7
Germany	373	357	362	363	363	364	365	0.0
Italy	177	201	204	209	213	217	222	0.3
Netherlands	85	99	107	107	109	110	112	0.2
Other Western Europe	418	520	533	522	535	548	566	0.3
Industrialized Asia	**563**	**692**	**699**	**749**	**769**	**800**	**830**	**0.7**
Japan	452	548	552	585	596	615	628	0.5
Australia/New Zealand	111	144	147	164	173	185	202	1.3
Total Industrialized	**4,606**	**5,366**	**5,329**	**5,769**	**6,012**	**6,275**	**6,548**	**0.9**
EE/FSU								
Former Soviet Union	**1,529**	**1,029**	**1,055**	**1,087**	**1,140**	**1,195**	**1,248**	**0.7**
Russia	991	690	711	730	730	768	797	0.5
Other FSU	538	339	345	357	410	427	451	1.1
Eastern Europe	**393**	**285**	**287**	**306**	**319**	**339**	**339**	**0.7**
Total EE/FSU	**1,923**	**1,314**	**1,342**	**1,393**	**1,459**	**1,533**	**1,587**	**0.7**
Developing Countries								
Developing Asia	**1,322**	**2,029**	**2,143**	**2,603**	**2,932**	**3,268**	**3,611**	**2.2**
China	681	931	1,000	1,291	1,490	1,699	1,915	2.7
India	196	319	322	392	451	519	584	2.5
South Korea	95	199	203	238	256	270	282	1.4
Other Asia	350	580	617	682	735	781	830	1.2
Middle East	**329**	**511**	**524**	**579**	**609**	**652**	**699**	**1.2**
Turkey	50	76	73	87	93	99	105	1.5
Other Middle East	280	435	451	492	516	553	594	1.2
Africa	**235**	**301**	**314**	**335**	**361**	**389**	**418**	**1.2**
Central and South America	**364**	**529**	**527**	**607**	**659**	**720**	**794**	**1.7**
Brazil	150	228	221	251	279	308	341	1.8
Other Central/South America	214	302	306	356	380	412	453	1.6
Total Developing	**2,250**	**3,371**	**3,508**	**4,123**	**4,561**	**5,029**	**5,522**	**1.9**
Total World	**8,779**	**10,052**	**10,179**	**11,286**	**12,032**	**12,838**	**13,656**	**1.2**

[a]Includes the 50 States and the District of Columbia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table B1; and System for the Analysis of Global Energy Markets (2004).

Appendix D

Projections of Oil Production Capacity and Oil Production in Three Cases:

- Reference
- High World Oil Price
- Low World Oil Price

Table D1. World Oil Production Capacity by Region and Country, Reference Case, 1990-2025
(Million Barrels per Day)

Region/Country	History (Estimates)		Projections			
	1990	2001	2010	2015	2020	2025
OPEC						
Persian Gulf						
Iran	3.2	3.7	4.0	4.3	4.7	4.9
Iraq	2.2	2.8	3.7	4.4	5.3	6.6
Kuwait	1.7	2.4	3.1	3.7	4.4	5.0
Qatar	0.5	0.6	0.6	0.7	0.8	0.8
Saudi Arabia	8.6	10.2	13.2	14.4	18.2	22.5
United Arab Emitates	2.5	2.7	3.3	3.9	4.6	5.2
Total Persian Gulf	**18.7**	**22.4**	**27.9**	**31.4**	**38.0**	**45.0**
Other OPEC						
Algeria	1.3	1.6	2.0	2.1	2.4	2.7
Indonesia	1.5	1.5	1.5	1.5	1.5	1.5
Libya	1.5	1.7	2.0	2.2	2.6	2.9
Nigeria	1.8	2.2	2.6	3.0	3.4	3.8
Venezuela	2.4	3.2	3.7	4.3	4.9	5.6
Total Other OPEC	**8.5**	**10.2**	**11.8**	**13.1**	**14.8**	**16.5**
Total OPEC	**27.2**	**32.6**	**39.7**	**44.5**	**52.8**	**61.5**
Non-OPEC						
Industrialized						
United States	9.7	9.0	9.5	9.3	8.9	8.6
Canada	2.0	2.8	3.5	4.6	4.8	4.9
Mexico	3.0	3.6	4.2	4.5	4.6	4.8
Australia	0.6	0.7	0.9	0.8	0.8	0.8
North Sea	4.2	6.3	5.9	5.4	5.1	4.6
Other	0.6	0.7	0.8	0.6	0.6	0.6
Total Industrialized	**20.1**	**23.1**	**24.8**	**25.2**	**24.8**	**24.3**
Eurasia						
China	2.8	3.3	3.6	3.5	3.5	3.4
Former Soviet Union	11.4	8.8	13.2	15.1	16.1	17.3
Eastern Europe	0.3	0.2	0.3	0.4	0.4	0.5
Total Eurasia	**14.5**	**12.3**	**17.1**	**19.0**	**20.0**	**21.2**
Other Non-OPEC						
Central and South America	2.4	3.8	4.7	5.7	6.3	6.8
Middle East	1.4	2.0	2.2	2.5	2.6	2.8
Africa	2.1	3.0	4.0	5.0	5.7	6.9
Asia	1.7	2.5	2.6	2.8	2.7	2.6
Total Other Non-OPEC	**7.6**	**11.3**	**13.5**	**16.0**	**17.3**	**19.1**
Total Non-OPEC	**42.2**	**46.7**	**55.4**	**60.2**	**62.1**	**64.6**
Total World	**69.4**	**79.3**	**95.1**	**104.7**	**114.9**	**126.1**

Note: OPEC = Organization of Petroleum Exporting Countries.

Sources: **History:** Energy Information Administration (EIA), Energy Markets and Contingency Information Division. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004); and U.S. Department of the Interior, U.S. Geological Survey, *World Petroleum Assessment 2000* (Reston, VA, July 2000).

Table D2. World Oil Production Capacity by Region and Country, High Oil Price Case, 1990-2025
(Million Barrels per Day)

Region/Country	History (Estimates) 1990	2001	Projections 2010	2015	2020	2025
OPEC						
Persian Gulf						
Iran	3.2	3.7	3.5	3.6	3.8	4.3
Iraq	2.2	2.8	2.9	3.2	3.7	4.6
Kuwait	1.7	2.4	2.3	2.5	2.9	3.4
Qatar	0.5	0.6	0.6	0.6	0.7	0.7
Saudi Arabia	8.6	10.2	9.4	9.8	12.9	16.0
United Arab Emitates	2.5	2.7	2.7	2.8	3.3	3.9
Total Persian Gulf	**18.7**	**22.4**	**21.4**	**22.5**	**27.3**	**32.9**
Other OPEC						
Algeria	1.3	1.6	1.6	1.7	2.0	2.2
Indonesia	1.5	1.5	1.5	1.5	1.5	1.5
Libya	1.5	1.7	1.7	1.8	2.1	2.4
Nigeria	1.8	2.2	2.2	2.4	2.8	3.3
Venezuela	2.4	3.2	3.2	3.4	3.9	4.5
Total Other OPEC	**8.5**	**10.2**	**10.2**	**10.8**	**12.3**	**13.9**
Total OPEC	**27.2**	**32.6**	**31.6**	**33.3**	**39.6**	**46.8**
Non-OPEC						
Industrialized						
United States	9.7	9.0	9.9	9.7	9.6	9.0
Canada	2.0	2.8	3.7	5.0	5.2	5.5
Mexico	3.0	3.6	4.4	4.8	5.0	5.2
Australia	0.6	0.7	0.9	0.8	0.8	0.8
North Sea	4.2	6.3	6.0	5.6	5.3	4.8
Other	0.6	0.7	0.7	0.7	0.7	0.6
Total Industrialized	**20.1**	**23.1**	**25.6**	**26.6**	**26.6**	**25.9**
Eurasia						
China	2.8	3.3	3.7	3.6	3.6	3.4
Former Soviet Union	11.4	8.8	13.9	16.2	17.4	19.0
Eastern Europe	0.3	0.2	0.3	0.4	0.4	0.4
Total Eurasia	**14.5**	**12.3**	**17.9**	**20.2**	**21.4**	**22.8**
Other Non-OPEC						
Central and South America	2.4	3.8	5.1	6.2	6.9	7.5
Middle East	1.4	2.0	2.4	2.7	2.9	3.1
Africa	2.1	3.0	4.6	5.5	6.8	8.2
Asia	1.7	2.5	2.8	2.9	3.0	3.0
Total Other Non-OPEC	**7.6**	**11.3**	**14.9**	**17.3**	**19.6**	**21.8**
Total Non-OPEC	**42.2**	**46.7**	**58.4**	**64.1**	**67.6**	**70.5**
Total World	**69.4**	**79.3**	**90.0**	**97.4**	**107.2**	**117.3**

Note: OPEC = Organization of Petroleum Exporting Countries.

Sources: **History:** Energy Information Administration (EIA), Energy Markets and Contingency Information Division. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004); and U.S. Department of the Interior, U.S. Geological Survey, *World Petroleum Assessment 2000* (Reston, VA, July 2000).

Table D3. World Oil Production Capacity by Region and Country, Low Oil Price Case, 1990-2025
(Million Barrels per Day)

Region/Country	History (Estimates)		Projections			
	1990	2001	2010	2015	2020	2025
OPEC						
Persian Gulf						
Iran	3.2	3.7	4.5	4.9	5.4	5.7
Iraq	2.2	2.8	4.4	5.3	6.4	7.2
Kuwait	1.7	2.4	3.6	4.3	5.1	5.7
Qatar	0.5	0.6	0.6	0.8	0.8	0.8
Saudi Arabia	8.6	10.2	16.8	19.1	25.0	31.5
United Arab Emitates	2.5	2.7	3.7	4.5	5.3	5.9
Total Persian Gulf	**18.7**	**22.4**	**33.6**	**38.9**	**48.0**	**56.8**
Other OPEC						
Algeria	1.3	1.6	2.1	2.3	2.6	3.0
Indonesia	1.5	1.5	1.5	1.5	1.5	1.5
Libya	1.5	1.7	2.1	2.4	2.7	3.1
Nigeria	1.8	2.2	3.0	3.9	4.6	5.2
Venezuela	2.4	3.2	4.3	4.7	5.2	6.1
Total Other OPEC	**8.5**	**10.2**	**13.0**	**14.8**	**16.6**	**18.9**
Total OPEC	**27.2**	**32.6**	**46.6**	**53.7**	**64.6**	**75.7**
Non-OPEC						
Industrialized						
United States	9.7	9.0	9.2	8.8	8.3	7.9
Canada	2.0	2.8	3.4	4.4	4.5	4.3
Mexico	3.0	3.6	4.1	4.4	4.5	4.7
Australia	0.6	0.7	0.8	0.8	0.7	0.7
North Sea	4.2	6.3	5.8	5.3	5.1	4.5
Other	0.6	0.7	0.7	0.7	0.6	0.6
Total Industrialized	**20.1**	**23.1**	**24.0**	**24.4**	**23.7**	**22.7**
Eurasia						
China	2.8	3.3	3.5	3.3	3.3	3.2
Former Soviet Union	11.4	8.8	12.9	14.7	15.7	16.8
Eastern Europe	0.3	0.2	0.3	0.4	0.4	0.4
Total Eurasia	**14.5**	**12.3**	**16.7**	**18.4**	**19.4**	**20.4**
Other Non-OPEC						
Central and South America	2.4	3.8	4.6	5.5	5.9	6.5
Middle East	1.4	2.0	2.2	2.4	2.4	2.6
Africa	2.1	3.0	3.8	4.8	5.4	6.5
Asia	1.7	2.5	2.7	2.6	2.6	2.6
Total Other Non-OPEC	**7.6**	**11.3**	**13.3**	**15.3**	**16.3**	**18.2**
Total Non-OPEC	**42.2**	**46.7**	**54.0**	**58.1**	**59.4**	**61.3**
Total World	**69.4**	**79.3**	**100.6**	**111.8**	**124.0**	**137.0**

Note: OPEC = Organization of Petroleum Exporting Countries.

Sources: **History:** Energy Information Administration (EIA), Energy Markets and Contingency Information Division. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004); and U.S. Department of the Interior, U.S. Geological Survey, *World Petroleum Assessment 2000* (Reston, VA, July 2000).

Table D4. World Oil Production by Region and Country, Reference Case, 1990-2025
(Million Barrels per Day)

Region/Country	History (Estimates) 1990	History (Estimates) 2001	Projections 2010	Projections 2015	Projections 2020	Projections 2025
Conventional Production	**66.7**	**75.7**	**88.1**	**95.7**	**104.9**	**115.5**
OPEC	**24.5**	**29.9**	**34.9**	**38.9**	**46.7**	**54.9**
Asia	1.5	1.4	1.3	1.3	1.3	1.4
Middle East	16.2	20.5	25.7	29.1	35.4	42.1
North Africa	2.7	3.0	3.0	3.1	3.6	4.0
West Africa	1.8	2.3	2.2	2.6	3.1	3.4
South America	2.3	2.7	2.7	2.8	3.3	4.0
Non-OPEC	**42.2**	**45.8**	**53.2**	**56.8**	**58.2**	**60.6**
Industrialized	**20.1**	**22.5**	**23.0**	**22.3**	**21.6**	**21.0**
United States	9.7	9.0	9.5	9.3	8.9	8.6
Canada	2.0	2.1	1.8	1.6	1.6	1.6
Mexico	3.0	3.6	4.2	4.5	4.6	4.8
Western Europe	4.6	6.9	6.4	5.9	5.5	5.0
Japan	0.1	0.1	0.1	0.1	0.1	0.1
Australia and New Zealand	0.7	0.8	1.0	0.9	0.9	0.9
Eurasia	**14.5**	**12.3**	**17.1**	**19.0**	**20.0**	**21.2**
China	**2.8**	**3.3**	**3.6**	**3.5**	**3.5**	**3.4**
Former Soviet Union	**11.4**	**8.8**	**13.2**	**15.1**	**16.1**	**17.3**
Russia	11.4	7.3	10.0	10.6	10.9	11.1
Caspian and Other FSU	0.0	1.5	3.2	4.5	5.2	6.2
Eastern Europe	**0.3**	**0.2**	**0.3**	**0.4**	**0.4**	**0.5**
Other Non-OPEC	**7.6**	**11.0**	**13.1**	**15.5**	**16.6**	**18.4**
Other Asia	1.7	2.5	2.6	2.8	2.7	2.6
Middle East	1.4	2.0	2.2	2.5	2.6	2.8
Africa	2.1	2.8	3.8	4.8	5.4	6.6
South and Central America	2.4	3.7	4.5	5.4	5.9	6.4
Nonconventional Production	**0.0**	**1.4**	**2.8**	**4.6**	**5.0**	**5.2**
United States	0.0	0.0	0.0	0.0	0.0	0.0
Other North America	0.0	0.7	1.7	3.0	3.2	3.3
Western Europe	0.0	0.0	0.0	0.0	0.0	0.0
Asia	0.0	0.0	0.0	0.0	0.0	0.0
Middle East	0.0	0.0	0.1	0.1	0.1	0.2
Africa	0.0	0.2	0.2	0.2	0.3	0.3
South and Central America	0.0	0.5	0.8	1.3	1.4	1.4
Liquids Production	**66.7**	**77.0**	**91.1**	**100.2**	**109.9**	**120.6**
OPEC	24.5	30.3	35.7	40.0	47.8	56.0
Non-OPEC	42.2	46.7	55.4	60.2	62.1	64.6
Persian Gulf Production as a Percentage of World Consumption	**24.3%**	**26.6%**	**28.1%**	**29.0%**	**32.1%**	**34.8%**

Notes: OPEC = Organization of Petroleum Exporting Countries. Conventional production includes crude oil (including lease condensates), natural gas liquids, other hydrogen hydrocarbons for refinery feedstocks, refinery gains, alcohol, and liquids produced from coal and other sources. Nonconventional liquids include production from oil sands, ultra-heavy oils, gas-to-liquids technologies, coal-to-liquids technologies, biofuel technologies, and shale oil. 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, System for the Analysis of Global Energy Markets (2004); and U.S. Department of the Interior, U.S. Geological Survey, *World Petroleum Assessment 2000* (Reston, VA, July 2000).

Table D5. World Oil Production by Region and Country, High Oil Price Case, 1990-2025
(Million Barrels per Day)

Region/Country	History (Estimates)		Projections			
	1990	2001	2010	2015	2020	2025
Conventional Production	**66.7**	**75.7**	**82.9**	**87.8**	**95.7**	**105.1**
OPEC	**24.5**	**29.9**	**27.2**	**27.9**	**33.5**	**40.1**
Asia	1.5	1.4	1.3	1.2	1.2	1.2
Middle East	16.2	20.5	18.8	19.7	24.4	29.9
North Africa	2.7	3.0	3.0	3.0	3.5	3.7
West Africa	1.8	2.3	2.0	2.1	2.4	2.9
South America	2.3	2.7	2.1	1.9	2.0	2.4
Non-OPEC	**42.2**	**45.8**	**55.7**	**59.9**	**62.2**	**65.0**
Industrialized	**20.1**	**22.5**	**23.6**	**23.0**	**22.6**	**21.7**
United States	9.7	9.0	9.8	9.5	9.4	8.8
Canada	2.0	2.1	1.8	1.7	1.6	1.6
Mexico	3.0	3.6	4.4	4.8	5.0	5.2
Western Europe	4.6	6.9	6.5	6.0	5.6	5.1
Japan	0.1	0.1	0.1	0.1	0.1	0.1
Australia and New Zealand	0.7	0.8	1.0	0.9	0.9	0.9
Eurasia	**14.5**	**12.3**	**17.9**	**20.2**	**21.4**	**22.9**
China	**2.8**	**3.3**	**3.7**	**3.6**	**3.6**	**3.5**
Former Soviet Union	**11.4**	**8.8**	**13.9**	**16.2**	**17.4**	**18.9**
Russia	11.4	7.3	10.5	11.3	11.6	11.9
Caspian and Other FSU	0.0	1.5	3.4	4.9	5.8	7.0
Eastern Europe	**0.3**	**0.2**	**0.3**	**0.4**	**0.4**	**0.5**
Other Non-OPEC	**7.6**	**11.0**	**14.2**	**16.7**	**18.2**	**20.4**
Other Asia	1.7	2.5	2.8	2.9	2.9	2.9
Middle East	1.4	2.0	2.4	2.7	2.8	3.1
Africa	2.1	2.8	4.2	5.4	6.2	7.5
South and Central America	2.4	3.7	4.8	5.7	6.3	6.9
Nonconventional Production	**0.0**	**1.4**	**3.7**	**5.7**	**7.0**	**8.0**
United States	0.0	0.0	0.1	0.2	0.2	0.2
Other North America	0.0	0.7	1.9	3.3	3.6	3.9
Western Europe	0.0	0.0	0.0	0.1	0.1	0.1
Asia	0.0	0.0	0.0	0.0	0.0	0.1
Middle East	0.0	0.0	0.1	0.1	0.2	0.3
Africa	0.0	0.2	0.4	0.1	0.6	0.8
South and Central America	0.0	0.5	1.2	1.9	2.3	2.6
Liquids Production	**66.7**	**77.0**	**86.6**	**93.6**	**103.0**	**112.7**
OPEC	24.5	30.3	28.2	29.5	35.4	42.2
Non-OPEC	42.2	46.7	58.4	64.1	67.6	70.5
Persian Gulf Production as a Percentage of World Consumption	**24.3%**	**26.6%**	**21.6%**	**21.0%**	**23.6%**	**26.5%**

Notes: OPEC = Organization of Petroleum Exporting Countries. Conventional production includes crude oil (including lease condensates), natural gas liquids, other hydrogen hydrocarbons for refinery feedstocks, refinery gains, alcohol, and liquids produced from coal and other sources. Nonconventional liquids include production from oil sands, ultra-heavy oils, gas-to-liquids technologies, coal-to-liquids technologies, biofuel technologies, and shale oil. 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, System for the Analysis of Global Energy Markets (2004); and U.S. Department of the Interior, U.S. Geological Survey, *World Petroleum Assessment 2000* (Reston, VA, July 2000).

Table D6. World Oil Production by Region and Country, Low Oil Price Case, 1990-2025
(Million Barrels per Day)

Region/Country	History (Estimates)		Projections			
	1990	2001	2010	2015	2020	2025
Conventional Production	**66.7**	**75.7**	**93.4**	**103.3**	**115.2**	**128.1**
OPEC	**24.5**	**29.9**	**41.5**	**48.4**	**59.2**	**70.3**
Asia	1.5	1.4	1.3	1.3	1.4	1.4
Middle East	16.2	20.5	30.7	36.7	45.5	54.0
North Africa	2.7	3.0	3.7	4.1	4.8	5.7
West Africa	1.8	2.3	2.6	3.0	3.7	4.3
South America	2.3	2.7	3.2	3.3	3.8	4.9
Non-OPEC	**42.2**	**45.8**	**51.9**	**54.9**	**56.0**	**57.8**
Industrialized	**20.1**	**22.5**	**22.4**	**21.7**	**20.8**	**19.8**
United States	9.7	9.0	9.2	8.8	8.3	7.9
Canada	2.0	2.1	1.8	1.7	1.6	1.5
Mexico	3.0	3.6	4.1	4.4	4.5	4.7
Western Europe	4.6	6.9	6.3	5.8	5.5	4.9
Japan	0.1	0.1	0.1	0.1	0.1	0.0
Australia and New Zealand	0.7	0.8	0.9	0.9	0.8	0.8
Eurasia	**14.5**	**12.3**	**16.7**	**18.4**	**19.4**	**20.4**
China	**2.8**	**3.3**	**3.5**	**3.3**	**3.3**	**3.2**
Former Soviet Union	**11.4**	**8.8**	**12.9**	**14.7**	**15.7**	**16.8**
Russia	11.4	7.3	9.8	10.4	10.7	10.9
Caspian and Other FSU	0.0	1.5	3.1	4.3	5.0	5.9
Eastern Europe	**0.3**	**0.2**	**0.3**	**0.4**	**0.4**	**0.4**
Other Non-OPEC	**7.6**	**11.0**	**12.8**	**14.8**	**15.8**	**17.6**
Other Asia	1.7	2.5	2.6	2.6	2.6	2.5
Middle East	1.4	2.0	2.2	2.4	2.4	2.6
Africa	2.1	2.8	3.6	4.6	5.2	6.3
South and Central America	2.4	3.7	4.4	5.2	5.6	6.2
Nonconventional Production	**0.0**	**1.4**	**2.6**	**4.0**	**4.3**	**4.1**
United States	0.0	0.0	0.0	0.0	0.0	0.0
Other North America	0.0	0.7	1.6	2.7	2.9	2.8
Western Europe	0.0	0.0	0.0	0.0	0.0	0.0
Asia	0.0	0.0	0.0	0.0	0.0	0.0
Middle East	0.0	0.0	0.0	0.0	0.0	0.0
Africa	0.0	0.2	0.2	0.2	0.2	0.2
South and Central America	0.0	0.5	0.8	1.1	1.2	1.1
Liquids Production	**66.7**	**77.0**	**96.1**	**107.4**	**119.5**	**132.5**
OPEC	24.5	30.3	42.1	49.3	60.1	71.2
Non-OPEC	42.2	46.7	54.0	58.1	59.4	61.3
Persian Gulf Production as a Percentage of World Consumption	**24.3%**	**26.6%**	**31.8%**	**34.1%**	**38.0%**	**40.7%**

Notes: OPEC = Organization of Petroleum Exporting Countries. Conventional production includes crude oil (including lease condensates), natural gas liquids, other hydrogen hydrocarbons for refinery feedstocks, refinery gains, alcohol, and liquids produced from coal and other sources. Nonconventional liquids include production from oil sands, ultra-heavy oils, gas-to-liquids technologies, coal-to-liquids technologies, biofuel technologies, and shale oil. 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, System for the Analysis of Global Energy Markets (2004); and U.S. Department of the Interior, U.S. Geological Survey, *World Petroleum Assessment 2000* (Reston, VA, July 2000).

Appendix E

Projections of Nuclear Generating Capacity

- Reference
- High Growth
- Low Growth

Table E1. World Nuclear Generating Capacity by Region and Country, Reference Case, 2000-2025
(Megawatts)

Region/Country	History			Projections				Average Annual Percent Change, 2001-2025
	2000	2001	2002	2010	2015	2020	2025	
Industrialized Countries								
North America	**109,238**	**109,537**	**110,035**	**116,489**	**118,042**	**119,252**	**116,395**	**0.3**
United States	97,860	98,159	98,657	100,570	102,123	102,603	102,603	0.2
Canada	10,018	10,018	10,018	14,477	14,477	15,207	12,351	0.9
Mexico	1,360	1,360	1,360	1,442	1,442	1,442	1,442	0.2
Western Europe	**125,926**	**125,926**	**125,530**	**125,002**	**119,541**	**103,856**	**92,737**	**-1.3**
United Kingdom	12,498	12,498	12,102	9,639	7,229	6,019	3,619	-5.0
France	63,073	63,073	63,073	66,610	68,210	69,810	69,810	0.4
Germany	21,283	21,283	21,283	17,320	12,669	1,345	0	-100.0
Netherlands	450	450	450	450	450	450	0	-100.0
Other	28,622	28,622	28,622	30,982	30,982	26,231	19,307	-1.6
Industrialized Asia	**43,245**	**43,245**	**43,602**	**50,308**	**53,148**	**56,882**	**54,281**	**1.0**
Japan	43,245	43,245	43,602	50,308	53,148	56,882	54,281	1.0
Total Industrialized	**278,409**	**278,708**	**279,167**	**291,798**	**290,730**	**279,989**	**263,413**	**-0.2**
EE/FSU								
Former Soviet Union	**33,796**	**34,746**	**34,746**	**41,226**	**42,750**	**39,280**	**35,615**	**0.1**
Russia	19,843	20,793	20,793	25,886	27,786	24,501	20,835	0.0
Other FSU	13,953	13,953	13,953	15,340	14,964	14,779	14,779	0.2
Eastern Europe	**10,676**	**11,588**	**11,684**	**12,175**	**13,830**	**12,965**	**12,965**	**0.5**
Total EE/FSU	**44,472**	**46,334**	**46,430**	**53,401**	**56,580**	**52,245**	**48,580**	**0.2**
Developing Countries								
Developing Asia	**22,814**	**23,016**	**27,987**	**40,939**	**52,844**	**61,772**	**66,712**	**4.5**
China	2,167	2,167	5,328	8,803	15,803	17,803	20,793	9.9
India	2,348	2,550	2,460	6,176	7,406	8,923	8,923	5.4
South Korea	12,990	12,990	14,890	17,646	21,446	26,257	27,607	3.2
Other	5,309	5,309	5,309	8,314	8,189	8,789	9,389	2.4
Middle East	**0**	**0**	**0**	**915**	**2,111**	**2,111**	**2,111**	**—**
Africa	**1,800**	**1,800**	**1,800**	**1,908**	**2,038**	**2,038**	**2,038**	**0.5**
Central/South America	**2,836**	**2,836**	**2,836**	**2,836**	**2,836**	**2,501**	**2,501**	**-0.5**
Brazil	1,901	1,901	1,901	1,901	1,901	1,901	1,901	0.0
Other	935	935	935	935	935	600	600	-1.8
Total Developing	**27,450**	**27,652**	**32,623**	**46,598**	**59,829**	**68,422**	**73,362**	**4.1**
Total World	**350,331**	**352,694**	**358,220**	**391,798**	**407,140**	**400,656**	**385,355**	**0.4**

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding.

Sources: **History:** International Atomic Energy Agency, *Nuclear Power Reactors in the World 2001* (Vienna, Austria, April 2003). **Projections:** Energy Information Administration (EIA), *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table A9; and EIA, Office of Coal, Nuclear, Electric and Alternate Fuels, based on detailed assessments of country-specific nuclear power plants.

Table E2. World Nuclear Generating Capacity by Region and Country, High Growth Case, 2000-2025
(Megawatts)

Region/Country	History 2000	History 2001	History 2002	Projections 2010	Projections 2015	Projections 2020	Projections 2025	Average Annual Percent Change, 2001-2025
Industrialized Countries								
North America	**109,238**	**109,537**	**110,035**	**116,489**	**119,502**	**121,712**	**122,712**	**0.5**
United States	97,860	98,159	98,657	100,570	102,123	102,603	102,603	0.2
Canada	10,018	10,018	10,018	14,477	15,937	16,667	16,667	2.1
Mexico	1,360	1,360	1,360	1,442	1,442	2,442	3,442	3.9
Western Europe	**125,926**	**125,926**	**125,530**	**130,819**	**134,039**	**141,639**	**148,037**	**0.7**
United Kingdom	12,498	12,498	12,102	10,619	10,639	12,639	11,674	-0.3
France	63,073	63,073	63,073	66,610	69,810	71,410	73,010	0.6
Germany	21,283	21,283	21,283	21,521	21,521	21,521	22,284	0.2
Italy	0	0	0	0	0	1,000	1,000	—
Netherlands	450	450	450	450	450	450	1,450	5.0
Other	28,622	28,622	28,622	31,618	31,618	34,618	38,618	1.3
Industrialized Asia	**43,245**	**43,245**	**43,602**	**52,555**	**59,671**	**65,371**	**72,771**	**2.2**
Japan	43,245	43,245	43,602	52,555	59,671	65,371	72,771	2.2
Total Industrialized	**278,409**	**278,708**	**279,167**	**299,862**	**313,211**	**328,721**	**343,519**	**0.9**
EE/FSU								
Former Soviet Union	**33,796**	**34,746**	**34,746**	**43,946**	**47,496**	**55,375**	**65,341**	**2.7**
Russia	19,843	20,793	20,793	28,606	31,156	37,686	43,742	3.1
Other FSU	13,953	13,953	13,953	15,340	16,340	17,689	21,599	1.8
Eastern Europe	**10,676**	**11,588**	**11,684**	**12,563**	**15,606**	**18,336**	**22,066**	**2.7**
Total EE/FSU	**44,472**	**46,334**	**46,430**	**56,509**	**63,102**	**73,711**	**87,407**	**2.7**
Developing Countries								
Developing Asia	**22,814**	**23,016**	**27,987**	**43,989**	**58,573**	**71,954**	**89,173**	**5.8**
China	2,167	2,167	5,328	10,903	17,903	20,903	24,903	10.7
India	2,348	2,550	2,460	6,176	8,960	11,860	12,123	6.7
South Korea	12,990	12,990	14,890	18,596	22,796	26,846	32,246	3.9
Other	5,309	5,309	5,309	8,314	8,914	12,345	19,901	5.7
Middle East	**0**	**0**	**0**	**915**	**2,111**	**3,111**	**7,111**	**—**
Turkey	0	0	0	0	0	0	2,000	—
Other	0	0	0	915	2,111	3,111	5,111	—
Africa	**1,800**	**1,800**	**1,800**	**2,038**	**2,298**	**2,558**	**4,818**	**4.2**
Central/South America	**2,836**	**2,836**	**2,836**	**2,836**	**4,757**	**4,757**	**5,757**	**3.0**
Brazil	1,901	1,901	1,901	1,901	3,130	3,130	4,130	3.3
Other	935	935	935	935	1,627	1,627	1,627	2.3
Total Developing	**27,450**	**27,652**	**32,623**	**49,778**	**67,739**	**82,380**	**106,859**	**5.8**
Total World	**350,331**	**352,694**	**358,220**	**406,149**	**444,053**	**484,813**	**537,786**	**1.8**

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding.

Sources: **History:** International Atomic Energy Agency, *Nuclear Power Reactors in the World 2001* (Vienna, Austria, April 2003). **Projections:** Energy Information Administration (EIA), *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table A9; and EIA, Office of Coal, Nuclear, Electric and Alternate Fuels, based on detailed assessments of country-specific nuclear power plants.

Table E3. World Nuclear Generating Capacity by Region and Country, Low Growth Case, 2000-2025
(Megawatts)

Region/Country	History			Projections				Average Annual Percent Change, 2001-2025
	2000	2001	2002	2010	2015	2020	2025	
Industrialized Countries								
North America	**109,238**	**109,537**	**110,035**	**116,489**	**115,185**	**113,990**	**110,731**	**0.0**
United States	97,860	98,159	98,657	100,570	102,123	102,603	102,603	0.2
Canada	10,018	10,018	10,018	14,477	11,621	9,946	6,687	-1.7
Mexico	1,360	1,360	1,360	1,442	1,442	1,442	1,442	0.2
Western Europe	**125,926**	**125,926**	**125,530**	**112,807**	**97,181**	**79,205**	**43,734**	**-4.3**
United Kingdom	12,498	12,498	12,102	6,019	2,994	1,814	1,259	-9.1
France	63,073	63,073	63,073	66,610	66,610	59,412	36,442	-2.3
Germany	21,283	21,283	21,283	12,669	1,345	0	0	-100.0
Netherlands	450	450	450	450	0	0	0	-100.0
Other	28,622	28,622	28,622	27,058	26,231	17,979	6,033	-6.3
Industrialized Asia	**43,245**	**43,245**	**43,602**	**49,396**	**49,470**	**42,492**	**38,074**	**-0.5**
Japan	43,245	43,245	43,602	49,396	49,470	42,492	38,074	-0.5
Total Industrialized	**278,409**	**278,708**	**279,167**	**278,692**	**261,836**	**235,687**	**192,539**	**-1.5**
EE/FSU								
Former Soviet Union	**33,796**	**34,746**	**34,746**	**35,954**	**32,365**	**27,457**	**16,638**	**-3.0**
Russia	19,843	20,793	20,793	22,174	18,585	13,678	7,689	-4.1
Other FSU	13,953	13,953	13,953	13,779	13,779	13,779	8,949	-1.8
Eastern Europe	**10,676**	**11,588**	**11,684**	**11,310**	**11,310**	**11,965**	**10,017**	**-0.6**
Total EE/FSU	**44,472**	**46,334**	**46,430**	**47,264**	**43,675**	**39,423**	**26,655**	**-2.3**
Developing Countries								
Developing Asia	**22,814**	**23,016**	**27,987**	**37,813**	**42,628**	**51,088**	**51,698**	**3.4**
China	2,167	2,167	5,328	8,603	9,793	14,793	16,514	8.8
India	2,348	2,550	2,460	3,964	5,689	7,821	7,572	4.6
South Korea	12,990	12,990	14,890	17,057	18,957	21,566	24,000	2.6
Other	5,309	5,309	5,309	8,189	8,189	6,909	3,612	-1.6
Middle East	**0**	**0**	**0**	**915**	**915**	**915**	**915**	**—**
Africa	**1,800**	**1,800**	**1,800**	**1,908**	**2,038**	**1,908**	**0**	**-100.0**
Central/South America	**2,836**	**2,836**	**2,836**	**2,501**	**2,501**	**1,275**	**1,275**	**-3.3**
Brazil	1,901	1,901	1,901	1,901	1,901	1,275	1,275	-1.7
Other	935	935	935	600	600	0	0	-100.0
Total Developing	**27,450**	**27,652**	**32,623**	**43,137**	**48,082**	**55,186**	**53,888**	**2.8**
Total World	**350,331**	**352,694**	**358,220**	**369,092**	**353,593**	**330,296**	**273,083**	**-1.1**

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding.

Sources: **History:** International Atomic Energy Agency, *Nuclear Power Reactors in the World 2001* (Vienna, Austria, April 2003). **Projections:** Energy Information Administration (EIA), *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), Table A9; and EIA, Office of Coal, Nuclear, Electric and Alternate Fuels, based on detailed assessments of country-specific nuclear power plants.

Appendix F

Comparisons With Other Forecasts, and Performance of Past *IEO* Forecasts for 1990, 1995, and 2000

Forecast Comparisons

Three organizations provide forecasts comparable with those in the *International Energy Outlook 2004* (*IEO2004*). The International Energy Agency (IEA) provides "business as usual" projections to the year 2030 in its *World Energy Outlook 2002*; Petroleum Economics, Ltd. (PEL) publishes world energy forecasts to 2020; and Petroleum Industry Research Associates (PIRA) provides projections to 2015. For this comparison, 2000 is used as the base year for all the forecasts (because IEA does not publish data for any other historical years), and the comparisons extend only to 2020. Although IEA's forecast extends to 2030, it does not publish a projection for 2025. In addition to forecasts from other organizations, the IEO2004 projections are also compared with those in last year's report (*IEO2003*).

Regional breakouts among the forecasting groups vary, complicating the comparisons. For example, *IEO2004* includes Mexico in North America and IEA includes Mexico in Organization for Economic Cooperation and Development (OECD) North America, but the two other forecasts include Mexico in Latin America. As a result, for purposes of this comparison, Mexico has been removed from North America in the *IEO2004* projections and added to Central and South America to form a "Latin America" country grouping that matches the other series. PIRA includes only Japan in industrialized Asia, whereas industrialized Asia in the *IEO2004* forecast comprises Japan, Australia, and New Zealand. *IEO2004* includes Turkey in the Middle East, but IEA includes Turkey, as well as the Czech Republic, Hungary, and Poland, in "OECD Europe" (which is designated as "Western Europe" for this comparison). PEL also places Turkey in Western Europe but includes the Czech Republic, Hungary, and Poland in Eastern Europe, as does *IEO2004*. Although most of the differences involve fairly small countries, they contribute to the variations among the forecasts.

All the forecasts provide projections out to the year 2010 (Table F1). The growth rates for energy consumption among the reference case forecasts for 2000-2010 range

Table F1. Comparison of Energy Consumption Growth Rates by Region, 2000-2010
(Average Annual Percent Growth)

Region	*IEO2004* Low Growth	*IEO2004* Reference	*IEO2004* High Growth	*IEO2003*	IEA	PIRA	PEL
Industrialized Countries	**0.7**	**1.0**	**1.3**	**1.1**	**1.1**	**0.8**	**1.1**
United States and Canada	0.9	1.2	1.5	1.3	1.1	0.7	1.3
Western Europe	0.3	0.6	0.9	0.8	1.1	0.9	0.9
Pacific	0.8	1.1	1.3	1.2	1.2	0.6[a]	0.6
EE/FSU	**0.6**	**1.2**	**2.0**	**2.4**	**1.8**	**2.5**	**1.4**
Developing Countries	**2.0**	**2.7**	**3.2**	**2.7**	**3.2**	**4.1**	**3.2**
Asia	2.5	3.2	3.8	3.2	3.4	4.1	3.6
China	3.3	4.0	4.6	3.9	3.2	4.7	4.1
Other Asia[b]	1.8	2.5	3.0	2.5	3.6	3.6	3.1
Middle East	1.2	2.1	2.5	2.1	2.8	3.0	3.2
Africa	1.1	2.0	2.7	1.9	3.3	2.4	2.6
Latin America	1.3	1.9	2.3	2.2	3.0	1.6	1.9
Total World	**1.2**	**1.7**	**2.1**	**1.9**	**1.9**	**2.0**	**1.9**

[a]Japan only.
[b]Other Asia includes India and South Korea.

Sources: ***IEO2004*:** Energy Information Administration (EIA), System for the Analysis of Global Energy Markets (2004). ***IEO2003*:** EIA, *International Energy Outlook 2002*, DOE/EIA-0484(2003) (Washington, DC, May 2003), Table A1, p. 181. **IEA:** International Energy Agency, *World Energy Outlook 2002* (Paris, France, September 2002), pp. 410-497. **PIRA:** PIRA Energy Group, *Retainer Client Seminar* (New York, NY, October 2003). **PEL:** Petroleum Economics, Ltd., *World Long Term Oil and Energy Outlook* (London, United Kingdom, April 2003).

from 1.7 percent per year (*IEO2004*) to 2.0 percent per year (PIRA). Among the forecasts, PIRA's regional expectations for energy demand growth vary the most from the *IEO2004* projections. The PIRA forecast, for the most part, projects higher growth rates for energy use in the developing world than does *IEO2004* (with the exception of Latin America) and in the EE/FSU region. PIRA's projected growth rates from 2000 to 2010 for China and other developing Asia, the Middle East, and the EE/FSU all fall above the projections in the *IEO2004* high economic growth case. On the other hand, PIRA is more pessimistic than *IEO2004* about the potential for energy demand growth in the industrialized regions. The PIRA growth rates for the United States and Canada and for industrialized Asia fall below those in the *IEO2004* low economic growth case.

The IEA projections for the developing world are also generally higher than the *IEO2004* projections. The IEA growth rates exceed the *IEO2004* growth rates projected for each developing region, except China. For China, IEA's projection of 3.2-percent annual growth in energy demand between 2000 and 2010 falls below the *IEO2004* low economic growth case; and its projected growth rates for other developing Asia, the Middle East, Africa, and Latin America all exceed the *IEO2004* high economic growth case. For the industrialized world, IEA largely agrees with *IEO2004*, except that the IEA growth rate for Western Europe (which in the IEA forecast includes Turkey, Hungary, Poland, and the Czech Republic) exceeds the rate in the *IEO2004* high economic growth case. In the PEL forecast, annual growth rates for energy demand fall within the range defined by the *IEO2004* low and high economic growth cases, except those for other developing Asia and the Middle East, both of which exceed those in the *IEO2004* high growth case.

The *IEO2004* reference case forecast is lower than in last year's outlook for the 2000 to 2010 time period, particularly for the EE/FSU and Latin American regions. For the EE/FSU, projected growth in energy use is substantially lower in *IEO2004* than in *IEO2003* (with demand growth averaging 1.2 percent and 2.4 percent per year, respectively, in the two forecasts). Expectations for efficiency gains in the coming decade have been raised in this year's report, accounting for the lower projected growth in energy demand over the 10-year period. In the case of Latin America, the lower forecast in *IEO2004* reflects a substantial lowering of expectations for economic growth in Mexico. From 2000 to 2010, Mexico's gross domestic product (GDP) was projected to expand at an average rate of 4.7 percent per year in *IEO2003*, compared with only 2.7 percent per year in *IEO2004*.

IEO2004, PIRA, and PEL provide forecasts for energy use in 2015 (Table F2), which is the end of the PIRA forecast horizon. Their projections for worldwide growth in

Table F2. Comparison of Energy Consumption Growth Rates by Region, 2000-2015
(Average Annual Percent Growth)

Region	*IEO2004* Low Growth	*IEO2004* Reference	*IEO2004* High Growth	*IEO2003*	PIRA	PEL
Industrialized Countries	**0.7**	**1.1**	**1.3**	**1.1**	**0.8**	**1.0**
United States and Canada	1.0	1.3	1.6	1.4	0.8	1.2
Western Europe	0.3	0.7	1.0	0.7	0.9	0.9
Pacific	0.7	1.0	1.3	1.2	0.6	0.3
EE/FSU	**0.7**	**1.4**	**2.2**	**2.1**	**2.5**	**1.5**
Former Soviet Union	0.7	1.4	2.2	2.3	—	1.6
Eastern Europe	0.7	1.3	1.9	1.6	—	1.3
Developing Countries	**2.0**	**2.8**	**3.4**	**2.9**	**3.4**	**3.1**
Asia	2.5	3.2	3.9	3.3	4.0	3.4
China	3.2	3.9	4.6	3.9	4.4	3.8
Other Asia[a]	1.8	2.6	3.3	2.7	3.6	3.1
Middle East	1.2	2.1	2.7	2.3	3.3	3.0
Africa	1.2	2.3	3.2	2.0	2.4	2.5
Latin America	1.5	2.0	2.5	2.6	1.9	2.1
Total World	**1.2**	**1.7**	**2.2**	**1.9**	**2.1**	**1.9**

[a]Other Asia includes India and South Korea.

Sources: ***IEO2004*:** Energy Information Administration (EIA), System for the Analysis of Global Energy Markets (2004). ***IEO2003*:** EIA, *International Energy Outlook 2003*, DOE/EIA-0484(2003) (Washington, DC, May 2003), Table A1, p. 181. **PIRA:** PIRA Energy Group, *Retainer Client Seminar* (New York, NY, October 2003), Tables II-4, II-6, and II-7. **PEL:** Petroleum Economics, Ltd., *World Long Term Oil and Energy Outlook* (London, United Kingdom, April 2003), Table 2i.

energy consumption between 2000 and 2015 are similar, ranging from 1.7 percent per year (*IEO2004*) to 2.1 percent per year (PIRA), with PEL expecting average annual growth of 1.9 percent. As it does for 2000-2010, PIRA forecasts much faster growth in energy use for the EE/FSU and for the developing regions from 2000 to 2015 than does *IEO2004*. The PIRA growth rates are higher than those in the *IEO2004* high economic growth case for "other Asia" and the Middle East. In the PEL forecast, 2000-2015 growth rates for energy demand in the developing are generally higher than the *IEO2004* reference case projections (except for China), but only one (for the Middle East) exceeds the *IEO2004* high economic growth case. The *IEO2004* reference case projections for energy demand growth in the United States and Canada and in industrialized Asia are higher than PIRA's, which fall below those of the *IEO2004* low growth case, as does the PEL growth rate for industrialized Asia.

The *IEO2004* reference case projection of worldwide growth in energy use, at 1.7 percent per year for the 2000-2015 period, is slightly lower than was projected in *IEO2003*. By region, the largest differences between the two forecasts are for the EE/FSU and Latin America. *IEO2004* projects a higher growth rate than *IEO2003* for energy use in Africa. The differences for the EE/FSU are largely attributed to the FSU region, where growth in energy use has been revised downward to 1.4 percent per year for the 2000-2015 time period, compared with 2.3 percent per year in *IEO2003*. The difference represents a reevaluation of the potential for energy efficiency improvements in the FSU. In *IEO2004,* efficiency improvements have been strengthened substantially, reflecting the expectation of more rapid replacement of old, inefficient capital stock.

For Latin America, the revisions from *IEO2003* to *IEO2004* for the 2000-2015 period are explained in large part by a lower assumption in this year's forecast for Mexico's GDP growth. In *IEO2003*, robust economic growth of 5.2 percent per year was projected for Mexico. The *IEO2004* reference case projects GDP growth of only 3.1 percent per year for Mexico, reflecting a less optimistic view of Mexico's ability to attract the foreign investment needed to support rapid economic expansion in the mid-term. For Africa, on the other hand, *IEO2004* projects average annual GDP growth of 4.1 percent per year from 2000 to 2015, up from the *IEO2003* projection of 3.7 percent per year, reflecting a reevaluation of Africa's economic potential in the mid-term..

IEO2004, PEL, and IEA provide energy consumption projections for 2020 (Table F3). The three forecasts have similar projections for energy demand growth from 2000 to 2020, all projecting an average 1.8-percent annual increase in the world's total energy consumption. The highest growth rates are projected for the developing world and the slowest for the industrialized world. The largest variations among the regional forecasts are for

Table F3. Comparison of Energy Consumption Growth Rates by Region, 2000-2020
(Average Annual Percent Growth)

Region	*IEO2004* Low Growth	*IEO2004* Reference	*IEO2004* High Growth	*IEO2003*	IEA	PEL
Industrialized Countries	**0.8**	**1.1**	**1.3**	**1.1**	**1.0**	**1.0**
United States and Canada	1.0	1.3	1.6	1.3	1.1	1.2
Western Europe	0.4	0.7	0.9	0.7	0.9	0.8
Pacific	0.7	1.0	1.3	1.1	1.0	0.5
EE/FSU	**0.5**	**1.5**	**2.3**	**1.9**	**1.5**	**1.6**
Former Soviet Union	0.5	1.5	2.3	2.0	—	1.7
Eastern Europe	0.6	1.5	2.1	1.8	—	1.6
Developing Countries	**2.0**	**2.8**	**3.5**	**2.9**	**3.1**	**3.0**
Asia	2.4	3.2	3.9	3.2	3.1	3.3
China	3.1	3.8	4.5	3.8	3.0	3.6
Other Asia[a]	1.8	2.6	3.3	2.7	3.3	3.0
Middle East	1.2	2.1	2.8	2.3	2.5	2.9
Africa	1.3	2.3	3.5	2.1	3.4	2.5
Latin America	1.6	2.2	2.7	2.7	2.9	2.1
Total World	**1.2**	**1.8**	**2.3**	**1.9**	**1.8**	**1.8**

[a]Other Asia includes India and South Korea.

Sources: ***IEO2004*:** Energy Information Administration (EIA), System for the Analysis of Global Energy Markets (2004). ***IEO2003*:** EIA, *International Energy Outlook 2003*, DOE/EIA-0484(2003) (Washington, DC, May 2003), Table A1, p. 181. **IEA:** International Energy Agency, *World Energy Outlook 2002* (Paris, France, September 2002), pp. 410-497. **PEL:** Petroleum Economics, Ltd., *World Long Term Oil and Energy Outlook* (London, United Kingdom, April 2003), Table 2i.

Africa, where growth expectations for energy use range from 2.3 percent per year (*IEO2004)* to 3.4 percent per year (IEA). IEA also remains more optimistic than the other forecasts about energy demand growth in Latin America, where the 2.9-percent annual rate projected by IEA exceeds the rate in the *IEO2004* high economic growth case. Both IEA and PEL expect higher growth in the Middle East than is projected in the *IEO2004* reference case, and PEL's projection is higher than the *IEO2004* high economic growth case. On the other hand, IEA expects much slower growth in energy use in China than do the other forecasts, and its projection of a 3.0-percent average annual increase in China's energy consumption is lower than the *IEO2004* low economic growth case.

As was the case for the 2000-2010 and 2000-2015 comparison periods, the EE/FSU is the region with the largest differences between the *IEO2004* and *IEO2003* reference case forecasts for 2000-2020; however, the differences are somewhat smaller when the longer time horizon to 2020 is considered. The impact of efficiency gains projected for the region in the early years of the forecast lessens after 2015, and the difference between the economic growth rates projected for 2000-2020 in the *IEO2004* and *IEO2003* reference case forecasts is only 0.4 percentage points, as compared with the difference of 1.2 percentage points for the 2000-2010 period.

The forecasts vary not only with respect to levels of total energy demand but also with respect to the mix of primary energy inputs. All the forecasts provide energy consumption projections by fuel in 2010 (Table F4). In terms of oil consumption, all the forecasts expect similar growth worldwide between 2000 and 2010: 1.4 percent per year in the PEL forecast and 1.7 percent per year in the three others. The *IEO2004* projection for worldwide growth in natural gas use is substantially lower than the previous year's (*IEO2003*) projection, and its projection for nuclear power is higher. The three other forecasts show much higher growth in natural gas consumption than does the *IEO2004* reference case, and all are higher than the *IEO2004* high economic growth case. The IEA forecast has a much higher projection for growth in renewable energy use than any of the other forecasts—2.8 percent per year, compared with 1.8 percent (PIRA and *IEO2004*) and 2.0 percent per year (PEL).

PEL, PIRA, and *IEO2004* provide world energy consumption projections by fuel for 2015 (Table F5). In the

Table F4. Comparison of World Energy Consumption Growth Rates by Fuel, 2000-2010
(Average Annual Percent Growth)

Fuel	*IEO2004* Low Growth	*IEO2004* Reference	*IEO2004* High Growth	*IEO2003*	IEA	PIRA	PEL
Oil	1.1	1.7	2.2	1.5	1.7	1.7	1.4
Natural Gas	1.3	1.7	2.3	2.5	3.0	2.8	2.9
Coal	1.0	1.4	1.8	1.7	1.4	2.3	1.7
Nuclear	1.1	1.6	1.6	1.3	1.1	0.8	1.3
Renewable/Other	1.3	1.8	2.3	2.4	2.8	1.8	2.0
Total	**1.2**	**1.7**	**2.1**	**1.9**	**1.9**	**2.0**	**1.9**

Sources: ***IEO2004*:** Energy Information Administration (EIA), System for the Analysis of Global Energy Markets (2004). ***IEO2003*:** EIA, *International Energy Outlook 2002*, DOE/EIA-0484(2003) (Washington, DC, May 2003), Table A1, p. 181. **IEA:** International Energy Agency, *World Energy Outlook 2002* (Paris, France, September 2002), pp. 410-497. **PIRA:** PIRA Energy Group, *Retainer Client Seminar* (New York, NY, October 2003). **PEL:** Petroleum Economics, Ltd., *World Long Term Oil and Energy Outlook* (London, United Kingdom, April 2003).

Table F5. Comparison of World Energy Consumption Growth Rates by Fuel, 2000-2015
(Average Annual Percent Growth)

Fuel	*IEO2004* Low Growth	*IEO2004* Reference	*IEO2004* High Growth	*IEO2003*	PIRA	PEL
Oil	1.2	1.8	2.4	1.7	1.7	1.5
Natural Gas	1.4	1.9	2.5	2.8	3.0	3.0
Coal	1.0	1.5	1.9	1.6	2.2	1.5
Nuclear	1.1	1.4	1.4	1.1	0.6	0.7
Renewable/Other	1.4	1.9	2.4	2.1	2.0	2.1
Total	**1.2**	**1.7**	**2.2**	**1.9**	**2.1**	**1.9**

Sources: ***IEO2004*:** Energy Information Administration (EIA), System for the Analysis of Global Energy Markets (2004). ***IEO2003*:** EIA, *International Energy Outlook 2003*, DOE/EIA-0484(2003) (Washington, DC, May 2003). **PIRA:** PIRA Energy Group, *Retainer Client Seminar* (New York, NY, October 2003). **PEL:** Petroleum Economics, Ltd., *World Long Term Oil and Energy Outlook* (London, United Kingdom, April 2003).

IEO2004 reference case, worldwide growth in energy consumption is expected to be slower (1.7 percent per year between 2000 and 2015) than in the PEL (1.9 percent per year) and PIRA (2.1 percent per year) forecasts. PEL and PIRA remain much more bullish in their projections for natural gas demand over this time period, in both cases exceeding the *IEO2004* high economic growth case. *IEO2004* projects growth in nuclear power that is double that in the two other forecasts, both of which fall below the *IEO2004* low growth case.

IEO2004, PEL, and IEA provide energy consumption projections for 2020 (Table F6). Although total growth in energy use is projected at 1.8 percent per year between 2000 and 2020 in each of the forecasts, the projected fuel mixes differ. Whereas *IEO2004* expects nuclear power generation to grow by 1.1 percent per year from 2000 to 2020, both IEA and PEL project much slower growth (0.3 percent and 0.2 percent per year, respectively), and both fall below the *IEO2004* low economic growth case. *IEO2004* projects smaller increases in natural gas demand than the other two forecasts, and PEL's projection of 3.0-percent average annual growth in natural gas consumption is higher than the *IEO2004* high growth case. IEA is more optimistic about the growth potential of renewable energy sources, projecting 2.7-percent annual growth between 2000 and 2020, as compared with the *IEO2004* projection of 1.8 percent in the reference case and 2.3 percent in the high economic growth case.

There has been a fairly significant shift in the projected mix of energy fuel use between the *IEO2003* and *IEO2004* forecasts, with lower growth in natural gas and higher growth in nuclear power expected in the *IEO2004* forecast. The growth rates in demand for other fuels in *IEO2004* are, for the most part, similar to those in *IEO2003*. For natural gas, the lower forecast in *IEO2004* is the result of a slightly lower assumption for worldwide economic growth, a slower projected decline in nuclear power generation (which competes with natural gas in the electric power sector), and concerns about the long-term ability of natural gas producers to bring sufficient resources to market at prices competitive with those of other fuels. For nuclear power, the increased growth rate results from a reassessment of prospects for nuclear power in light of higher capacity utilization rates reported for many existing nuclear facilities and the expectation that fewer retirements of existing plants will occur than previously projected.

Performance of Past *IEO* Forecasts for 1990, 1995, and 2000

In an effort to measure how well the *IEO* projections have estimated future energy consumption trends over the 19-year history of the series, a comparison of *IEO* forecasts produced for the years 1990, 1995, and 2000 is presented here. The forecasts are compared with actual data published in EIA's *International Energy Annual 2001*, 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.

The *IEO* has been published since 1985. In *IEO85*, midterm projections were derived only for the world's market economies. That is, no projections were prepared 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 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.

Table F6. Comparison of World Energy Consumption Growth Rates by Fuel, 2000-2020
(Average Annual Percent Growth)

Fuel	*IEO2004* Low Growth	*IEO2004* Reference	*IEO2004* High Growth	*IEO2003*	IEA	PEL
Oil	1.2	1.8	2.5	1.7	1.7	1.5
Natural Gas	1.5	2.1	2.7	2.8	2.7	3.0
Coal	1.0	1.5	2.0	1.6	1.4	1.4
Nuclear	0.9	1.1	1.1	0.8	0.3	0.2
Renewable/Other	1.3	1.8	2.3	1.9	2.7	2.2
Total	**1.2**	**1.8**	**2.3**	**1.9**	**1.8**	**1.8**

Sources: ***IEO2004*:** Energy Information Administration (EIA), System for the Analysis of Global Energy Markets (2004). ***IEO2003*:** EIA, *International Energy Outlook 2003*, DOE/EIA-0484(2003) (Washington, DC, May 2003). **IEA:** International Energy Agency, *World Energy Outlook 2002* (Paris, France, September 2002). **PEL:** Petroleum Economics, Ltd., *World Long Term Oil and Energy Outlook* (London, United Kingdom, April 2003).

Regional aggregations have changed from report to report. In 1990, the report coverage was expanded for the first time from only the market economies to the entire world. Projections for China, the FSU, and other CPE countries were provided separately. Starting with *IEO94*, the regional presentation was changed from market economies and CPE countries to OECD, Eurasia (China, FSU, and Eastern Europe), and “Rest of World.” Beginning in 1995 and essentially continuing until the current issue, the regional presentation changed to further group the world according to economic development: industrialized nations (essentially the OECD before the entry of South Korea and the Eastern European nations, the Czech Republic, Hungary, Poland, and Slovakia), the transitional economies of the EE/FSU, and the developing world (including China and India).

The forecast time horizon has also changed over the years (Table F7). In the first edition of the report, *IEO85*, projections were made for 1990 and 1995. *IEO86* saw the addition of projection year 2000. In *IEO91*, forecasts were no longer published for 1990, but forecasts for 2010 were added to the report. The projection horizon remained the same until *IEO96*, when projection year 2015 was added. In 1998, the forecast was extended again, out to 2020. The *IEO2003* and *IEO2004* forecasts extend to 2025.

Comparisons of Forecasts for Market Economies

Projections for market economies were made in the eight issues of the *IEO* that were published between 1985 and 1993 (no *IEO* was published in 1988). Historical data for total regional energy consumption in 1990 show that the *IEO* projections from those early years were consistently lower than the actual data for the market economies. For the four editions of the *IEO* printed between 1985 and 1989 in which 1990 projections were presented, total projected energy consumption in the market economies ran between 3 and 7 percent below the actual amounts published in the *International Energy Annual 2000* (Figure F1).

In addition, market economy projections for 1995 in the 1985 through 1993 *IEO* reports (EIA did not release forecasts for 1995 after the 1993 report) were consistently lower than the actual, historical 1995 data (Figure F2). Most of the difference is attributed to those market economy 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 was, as one might expect, the most accurate of the forecasts for 1995, but its projection for OPEC and the other market economy countries was still more than 10 percent below the actual number.

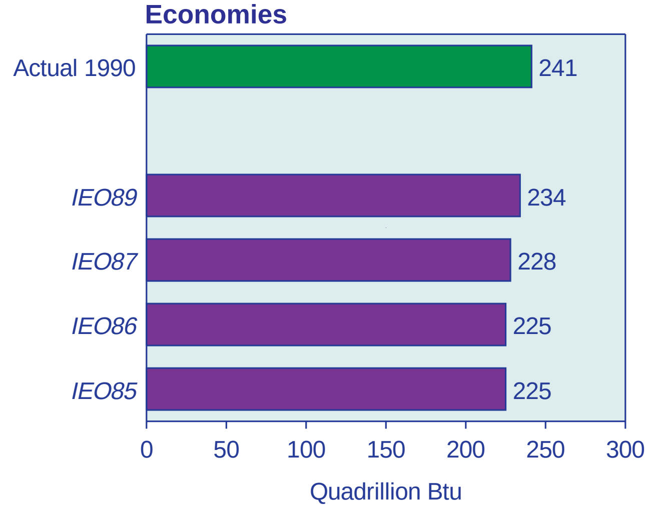
Similarly to the year 1995 projections, year 2000 projections were also consistently lower than actual 2000 data in each of the *IEOs* published between 1986 and 1993 (Figure F3). The consumption estimates for the market economies increased in each edition, from 265 quadrillion Btu in *IEO86* to 292 quadrillion Btu in *IEO93*. As late as 1993, the *IEO* forecasts were underestimating consumption of all energy sources in the market economies, by between 2 percent (oil) and 7 percent (natural gas and nuclear power).

Table F7. Years Included in *IEO* Projections by Edition, 1985-2004

Edition	1990	1995	2000	2005	2010	2015	2020	2025
IEO85	x	x						
IEO86	x	x	x					
IEO87	x	x	x					
IEO89	x	x	x					
IEO90		x	x		x			
IEO91		x	x		x			
IEO92		x	x		x			
IEO93		x	x		x			
IEO94			x	x	x			
IEO95			x	x	x			
IEO96		x	x	x	x	x		
IEO97			x	x	x	x		
IEO98			x	x	x	x	x	
IEO99			x	x	x	x	x	
IEO2000 . .				x	x	x	x	
IEO2001 . .				x	x	x	x	
IEO2002 . .				x	x	x	x	
IEO2003 . .				x	x	x	x	x
IEO2004 . .					x	x	x	x

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

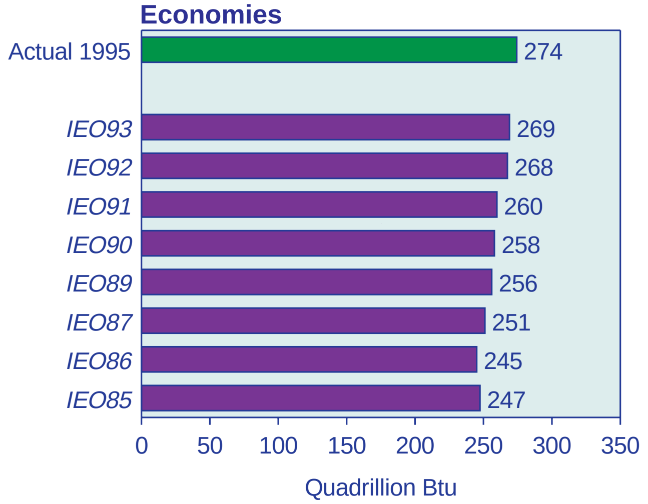
Figure F1. Comparison of *IEO* Forecasts with 1990 Energy Consumption in Market Economies



Sources: Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/, and *International Energy Outlook*, DOE/EIA-0484 (Washington, DC, various years).

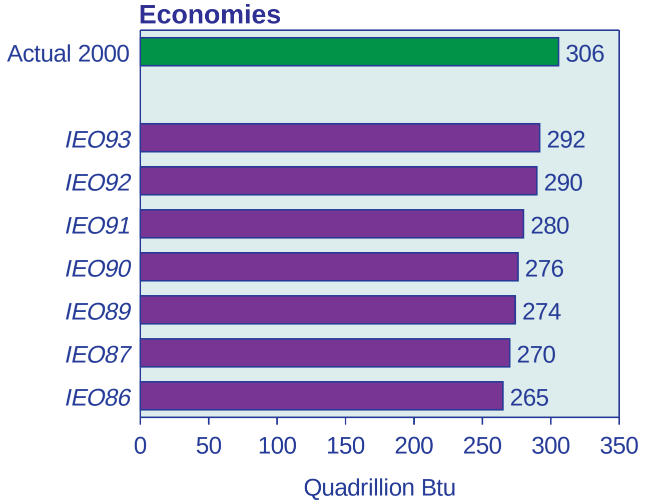
As noted above, in the 1994 edition of the *IEO*, the regional aggregation "market economies" was dropped altogether and replaced with delineation of member countries of the OECD, Eurasia, and Rest of World (ROW). As a result of that reorganization, it is not possible to recreate a forecast for the CPE countries: except for China, the FSU, and Eastern Europe, the remaining CPE countries—noted above—were included in "other ROW."

Figure F2. Comparison of *IEO* Forecasts with 1995 Energy Consumption in Market Economies



Sources: Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/, and *International Energy Outlook*, DOE/EIA-0484 (Washington, DC, various years).

Figure F3. Comparison of *IEO* Forecasts with 2000 Energy Consumption in Market Economies



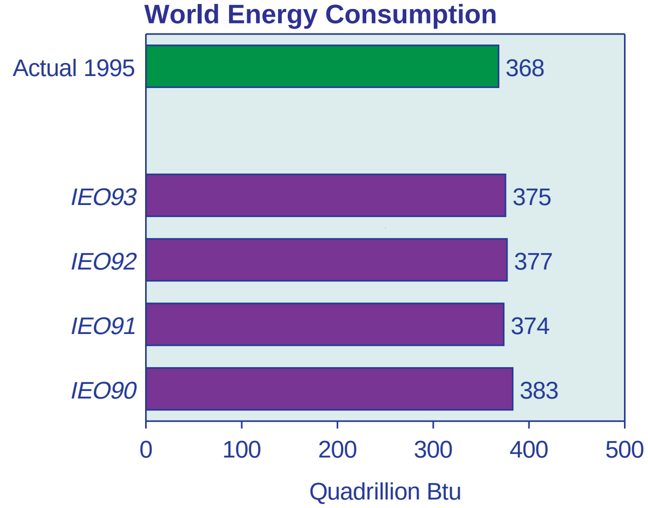
Sources: Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/, and *International Energy Outlook*, DOE/EIA-0484 (Washington, DC, various years).

Comparisons of Forecasts for Year 1995

IEO90 marked the first release of a worldwide energy consumption forecast. In *IEO90* through *IEO93*, the forecasts for worldwide energy demand in 1995 were between 1 and 4 percent higher than the actual amounts consumed (Figure F4). Much of the difference can be explained by the unanticipated collapse of the Soviet Union economies in the early 1990s. The *IEO* forecasters could not foresee the extent to which energy consumption would fall in the FSU region. In *IEO90*, total energy consumption in the FSU was projected to reach 67 quadrillion Btu in 1995. The projection was reduced steadily in the next three *IEO* reports, but even in *IEO93* energy demand for 1995 in the FSU region was projected to be 53 quadrillion Btu, as compared with actual 1995 energy consumption of 43 quadrillion Btu—a difference equivalent to about 5 million barrels of oil per day.

Forecasts for 1995 can also be compared in terms of their depiction of the fuel mix. Every *IEO* after 1990 projected the share of each energy source relative to total energy consumption within 3.5 percentage points of the actual 1995 distribution. The earliest *IEOs* tended to be too optimistic about the growth of coal use in the market economies (Figure F5) and too pessimistic about the recovery of oil consumption after the declines in the early 1980s that followed the price shocks caused by oil embargoes in 1973 and 1974 and the 1979-1980 revolution in Iran (Figure F6). The *IEO85* and *IEO86* reports projected that oil would account for only about 40 percent of total energy consumption for the market economies in 1995, whereas oil actually accounted for 45 percent of the total in 1995.

Figure F4. Comparison of *IEO* Forecasts with 1995 World Energy Consumption



Sources: Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/, and *International Energy Outlook*, DOE/EIA-0484 (Washington, DC, various years).

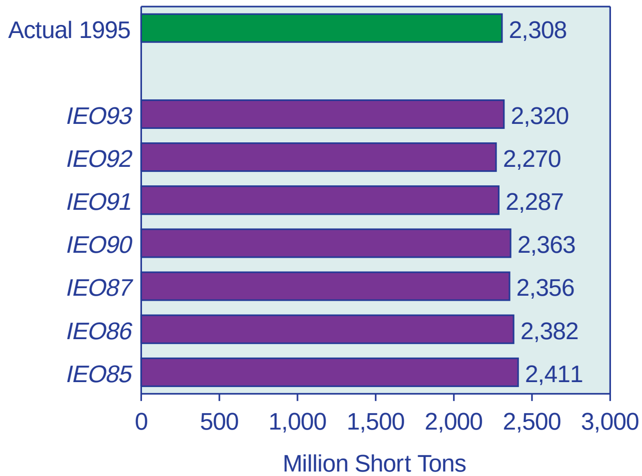
The 1995 forecasts for world coal consumption that appeared in the *IEOs* printed between 1990 and 1993 were consistently high, between 3 and 19 percent higher than actual coal use (Figure F7), largely because of overestimates for the FSU and Eastern Europe—regions that experienced substantial declines in coal consumption during the years following the collapse of the Soviet Union. Most of the projections for the FSU by fuel were greater than the actual consumption numbers, with the exception of hydroelectricity and other renewable resources (Figure F8). Natural gas use did not decline as much as oil and coal use, because gas is a plentiful resource in the region and was used extensively to fuel the domestic infrastructure; however, even the *IEO* estimates for 1995 natural gas use were 16 to 22 percent higher than the actual use.

The *IEO* projections for total energy consumption in China were below the actual 1995 consumption level in *IEO90* (by 13 percent) and *IEO91* (by 8 percent) but higher in *IEO92* (by 6 percent) and about the same in *IEO93*. The underestimates in the earlier *IEOs* balanced, in part, the overestimates for the EE/FSU countries; however, even the 4- to 17-percent underestimate of projected 1995 coal use in China could not make up for the 31- to 55-percent overestimate of FSU coal use. In terms of other fuels, the *IEO* forecasts consistently overestimated China's gas consumption and underestimated its oil consumption. Nuclear power forecasts were fairly close for China, within 5 percent of the actual consumption (Figure F9). It is noteworthy, however, that consumption of natural gas and nuclear power was quite small in 1995, so that any variation between actual historical consumption and the projections results in a large percentage difference. EIA consistently underestimated economic growth in China. As late as 1993, EIA expected GDP in China to grow by about 7.3 percent per year during the decade of the 1990s, whereas it actually grew by 10.7 percent per year between 1990 and 1995.

Comparisons of Forecasts for Year 2000

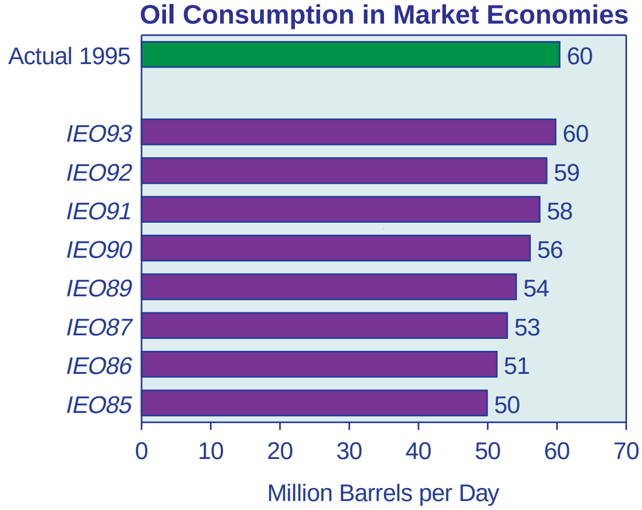
Ten editions of the *IEO* report contained worldwide forecasts for the year 2000 (*IEO90* through *IEO99*). The forecasts of total world energy consumption for 2000 were all above, but within 5 percent of, the actual total

Figure F5. Comparison of *IEO* Forecasts with 1995 Coal Consumption in Market Economies



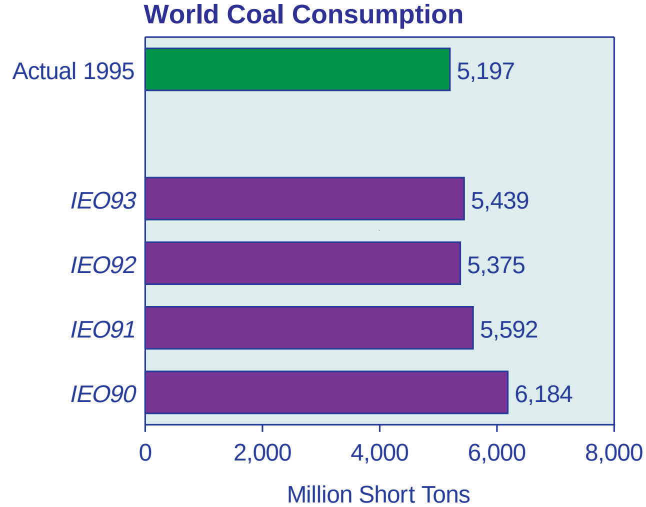
Sources: Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/, and *International Energy Outlook*, DOE/EIA-0484 (Washington, DC, various years).

Figure F6. Comparison of *IEO* Forecasts with 1995 Oil Consumption in Market Economies



Sources: Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/, and *International Energy Outlook*, DOE/EIA-0484 (Washington, DC, various years).

Figure F7. Comparison of *IEO* Forecasts with 1995 World Coal Consumption

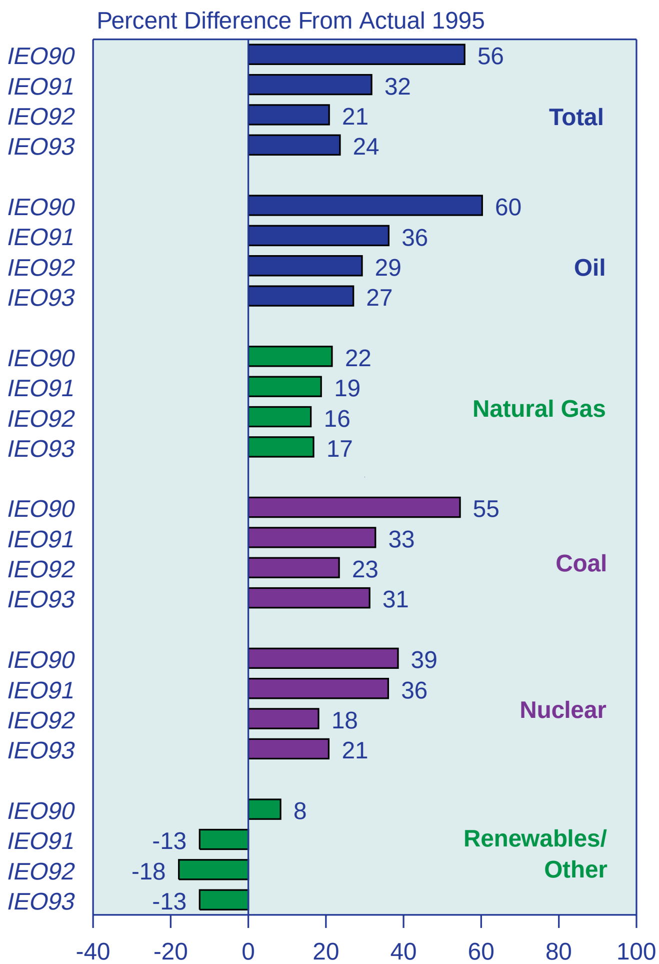


Sources: Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/, and *International Energy Outlook*, DOE/EIA-0484 (Washington, DC, various years).

(Figure F10). *IEO97* provided the highest estimate of world energy use in 2000. This may seem surprising at first glance, but it is also true that the economic recession that would take hold in 1998 among the emerging economies of southeast Asia had not occurred and was not foreseen in the *IEO97* forecast. In fact, *IEO97* overestimated year 2000 energy use in developing Asia by 10 quadrillion Btu, or about 14 percent (Figure F11), and in industrialized Asia by 2 quadrillion Btu (8 percent). Projections for the EE/FSU in *IEO97* were also too optimistic, overestimating the rate of economic recovery in the region and as a result overestimating the growth in energy consumption by 7 quadrillion Btu (13 percent). *IEO97* did not anticipate the August 1998 devaluation of the Russian ruble and the economic recession that followed in the FSU region. By *IEO99*, total EE/FSU energy use had been adjusted downward to 52 quadrillion Btu—just slightly lower than the region's actual consumption in 2000.

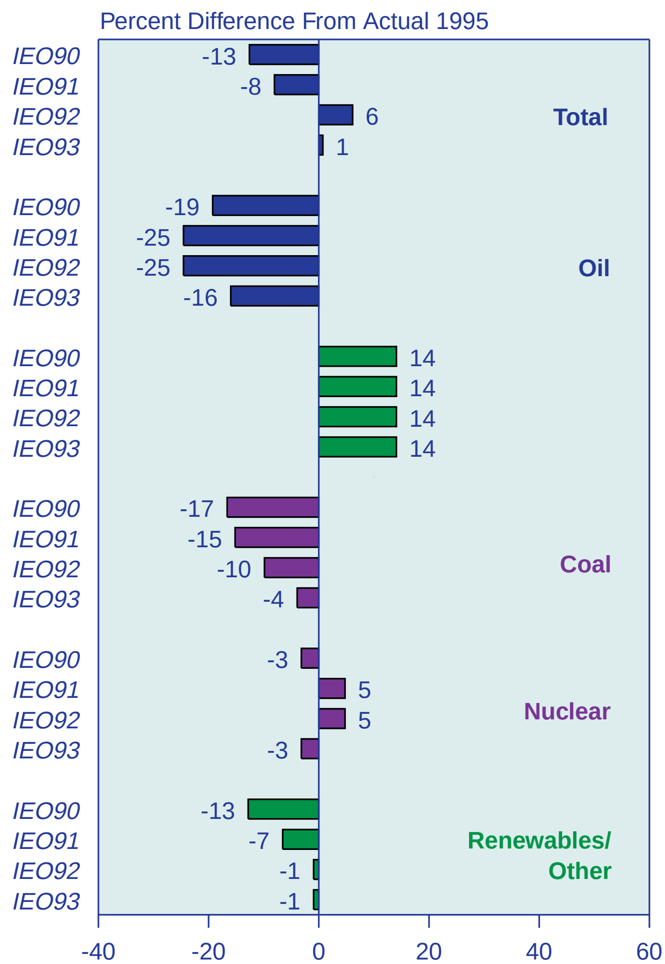
The projections for year 2000 by fuel were mixed in terms of accuracy. For all energy sources except coal, total world consumption forecasts fell within 12 percent of the actual levels. As was the case with forecasts for the years 1990 and 1995, world coal consumption projections were consistently high relative to actual consumption in 2000. The world coal forecast presented in *IEO90* was 30 percent higher than actual 2000 values. The forecasts for the CPE countries were responsible for the large discrepancy between projected *IEO90* and actual coal consumption in 2000. In fact, *IEO90* projected that the market economies would consume 2,801 million short tons of coal in 2000, and the actual estimate for coal use among the market economies was 2,904. However, in

Figure F8. Comparison of *IEO* Forecasts with 1995 Energy Consumption in the Former Soviet Union by Fuel Type



Sources: Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/, and *International Energy Outlook*, DOE/EIA-0484 (Washington, DC, various years).

Figure F9. Comparison of *IEO* Forecasts with 1995 Energy Consumption in China by Fuel Type



Sources: Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/, and *International Energy Outlook*, DOE/EIA-0484 (Washington, DC, various years).

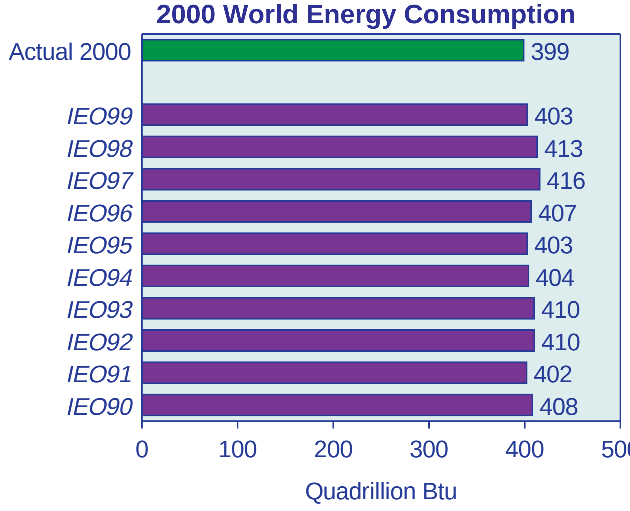
the CPE countries—including the EE/FSU—*IEO90* projected that coal use would climb to 3,841 million short tons in 2000, whereas actual coal consumption was only 2,211 million short tons.

Much of the discrepancy between the *IEO90* projection and actual 2000 coal consumption can be attributed to the FSU. As noted above, *IEO90* did not foresee the collapse of the Soviet regime in 1990 when the report projections were prepared. Indeed, coal use in the FSU in *IEO90* was expected to expand to 1,132 million short tons in 2000, whereas in reality coal use in the FSU began to decline precipitously after 1990, hitting a low of 391 million short tons in 1998 before edging up somewhat to 421 million short tons in 2000. The story was similar for Eastern Europe and the other CPE countries (excluding China), where coal use in 2000 was overestimated by 157 percent in *IEO90*.

The year 2000 forecasts for oil, natural gas, and hydroelectricity and other renewable energy sources were, for the most part, higher than actual levels. In contrast, projections for nuclear power were consistently lower than the actual 2000 values. Interestingly, the forecasts for the United States were largely responsible for the underestimation. Even in *IEO99*—the latest *IEO* that included projections for 2000—analysts were expecting nuclear power to begin to decline. In *IEO90* there was widespread pessimism about the future of nuclear power in the mid-term, given the aftermath of Chernobyl and the problems associated with nuclear waste disposal. In the political climate of the early 1990s, *IEO90* could not anticipate the life extensions and consistently improving efficiencies that have allowed nuclear power plants to generate more electricity and operate with shorter downtimes for maintenance, even without expanding their installed capacities.

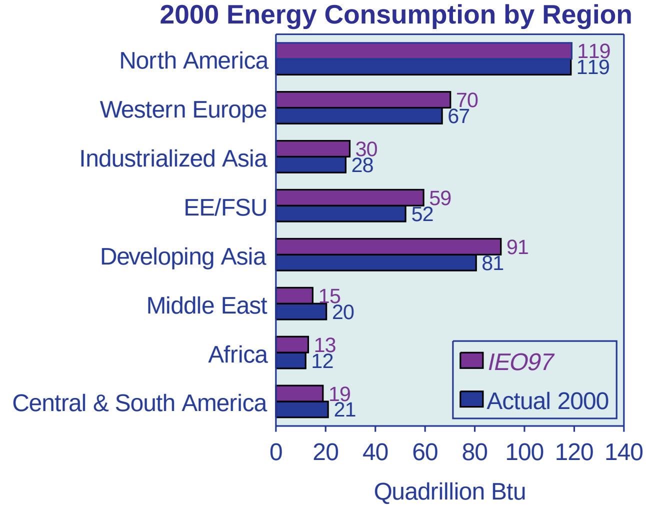
The comparison of *IEO* projections and historical data in the context of political and social events underscores the importance of those events in shaping the world's energy markets. Such comparisons also point out how important a model's assumptions are to the derivation of accurate forecasts. The political and social upheaval in the EE/FSU dramatically affected the accuracy of the projections for the region. If higher economic growth rates had been assumed for China, more accurate forecasts for that region might have been achieved. It is important for users of the *IEO* or any other projection series to realize the limitations of the forecasts. Failing an ability to predict future volatility in social, political, or economic events, the projections should be used as a plausible path or trend for the future and not as a precise prediction of future events.

Figure F10. Comparison of *IEO* Forecasts with 2000 World Energy Consumption



Sources: Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/, and *International Energy Outlook*, DOE/EIA-0484 (Washington, DC, various years).

Figure F11. Comparison of *IEO97* Forecasts with 2000 Energy Consumption by Region



Sources: Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/, and *International Energy Outlook 1997*, DOE/EIA-0484(97) (Washington, DC, April 1997).

Appendix G

System for the Analysis of Global Energy Markets (SAGE)

The projections of world energy consumption appearing in this year's *International Energy Outlook* (*IEO*) are based on the Energy Information Administration's (EIA's) new international energy modeling tool, System for the Analysis of Global Energy markets (SAGE). SAGE is an integrated set of regional models that provide a technology-rich basis for estimating regional energy consumption. For each region, reference case estimates of 42 end-use energy service demands (e.g., car, commercial truck, and heavy truck road travel; residential lighting; steam heat requirements in the paper industry) are developed on the basis of economic and demographic projections. Projections of energy consumption to meet the energy demands are estimated on the basis of each region's existing energy use patterns, the existing stock of energy-using equipment, and the characteristics of available new technologies, as well as new sources of primary energy supply.

Period-by-period market simulations aim to provide each region's energy services at minimum cost by simultaneously making end-use equipment and primary energy supply decisions. For example, in SAGE, if there is an increase in residential lighting energy service, either existing generation equipment must be used more intensively or new equipment must be installed. The choice of generation equipment (type and fuel) incorporates analysis of both the characteristics of alternative generation technologies and the economics of primary energy supply.

Although the modeling system used to develop the projections has changed, this year's *IEO* maintains the same level of fuel detail and the same tabular format. As in the past, the *IEO* 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. Projections of carbon dioxide emissions resulting from fossil fuel use are also provided. All projections are computed in 5-year intervals through the year 2025. Further, more detailed tables that emphasize the end-use demand-driven nature of SAGE will be considered for future reports.

SAGE provides projections for 15 regions or countries, including the North American countries of the United States, Canada, and Mexico; Western Europe; Japan; Australia/New Zealand; Eastern Europe; the former Soviet Union (FSU); China; India; South Korea; other developing Asia; the Middle East; Africa; and Central and South America. An offline procedure is used to develop projections for individual countries that fall into the SAGE regions, including the United Kingdom, France, Germany, Italy, and the Netherlands in Western Europe; Russia in the FSU; Turkey in the Middle East; and Brazil in Central and South America.

Projections of world oil prices over the forecast horizon are provided to SAGE 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 SAGE model is available in a two-volume set. The first volume provides a general understanding of the model's design, theoretical basis, necessary user-defined assumptions, and output. It also lists the software necessary to develop and analyze the results of SAGE-based policy and energy market scenarios. In addition, Volume I includes a Reference Guide, which explains each equation in detail. The second volume serves as a User's Guide for those actively developing SAGE-based scenario analyses. The documentation is available on EIA's web site in the model documentation section of "Current Publications" (http://www.eia.doe.gov/bookshelf/docs.html).