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Electronic Access and Related Reports

The *IEO2003* will be available on CD-ROM and the EIA Home Page (*http://www.eia.doe.gov/oiaf/ieo/index.html*) by May 2003, 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(2003).pdf*.

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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 2003* (*IEO2003*) presents an assessment by the Energy Information Administration (EIA) of the outlook for international energy markets through 2025. U.S. projections appearing in *IEO2003* are consistent with those published in EIA's *Annual Energy Outlook 2003* (*AEO2003*), which was prepared using the National Energy Modeling System (NEMS). *IEO2003* 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 *IEO2003* projections are based on U.S. and foreign government policies in effect on October 1, 2002.

Projections in *IEO2003* are displayed according to six basic country groupings (Figure 1). The industrialized region includes projections for nine individual countries—the United States, Canada, Mexico, Japan, France, Germany, Italy, the Netherlands, and the United Kingdom—plus the subgroups Other Europe and Australia / New Zealand. The developing countries are represented by four separate regional subgroups: developing Asia, Africa, Middle East, and Central and South America. China, India, and South Korea are represented in developing Asia; Brazil is represented in Central and South America; and Turkey is represented in the Middle East. The nations of Eastern Europe and the former Soviet Union (EE / FSU) are considered as a separate country grouping.

The report begins with a review of world trends in energy demand. The historical time frame begins with data from 1970 and extends to 2001, providing readers with a 31-year historical view of energy demand. In *IEO2003*, for the first time, the *IEO* projections extend to 2025, giving readers a 24-year forecast period.

High economic growth and low economic growth cases were developed to depict a set of alternative growth paths for the energy forecast. The two 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. Comparisons of the *IEO2003* projections with other available international energy forecasts are included in the first chapter, as well as comparisons of historical data with projections published in earlier *IEO*s.

The next part of the report is organized by energy source. Regional consumption projections for oil, natural gas, coal, nuclear power, and renewable energy (hydroelectricity, geothermal, wind, solar, and other renewables) are presented in the five fuel chapters, along with a review of the current status of each fuel on a worldwide basis. A chapter on energy consumed by electricity producers follows. The report ends with a discussion of energy and environmental issues, with particular attention to the outlook for global carbon emissions.

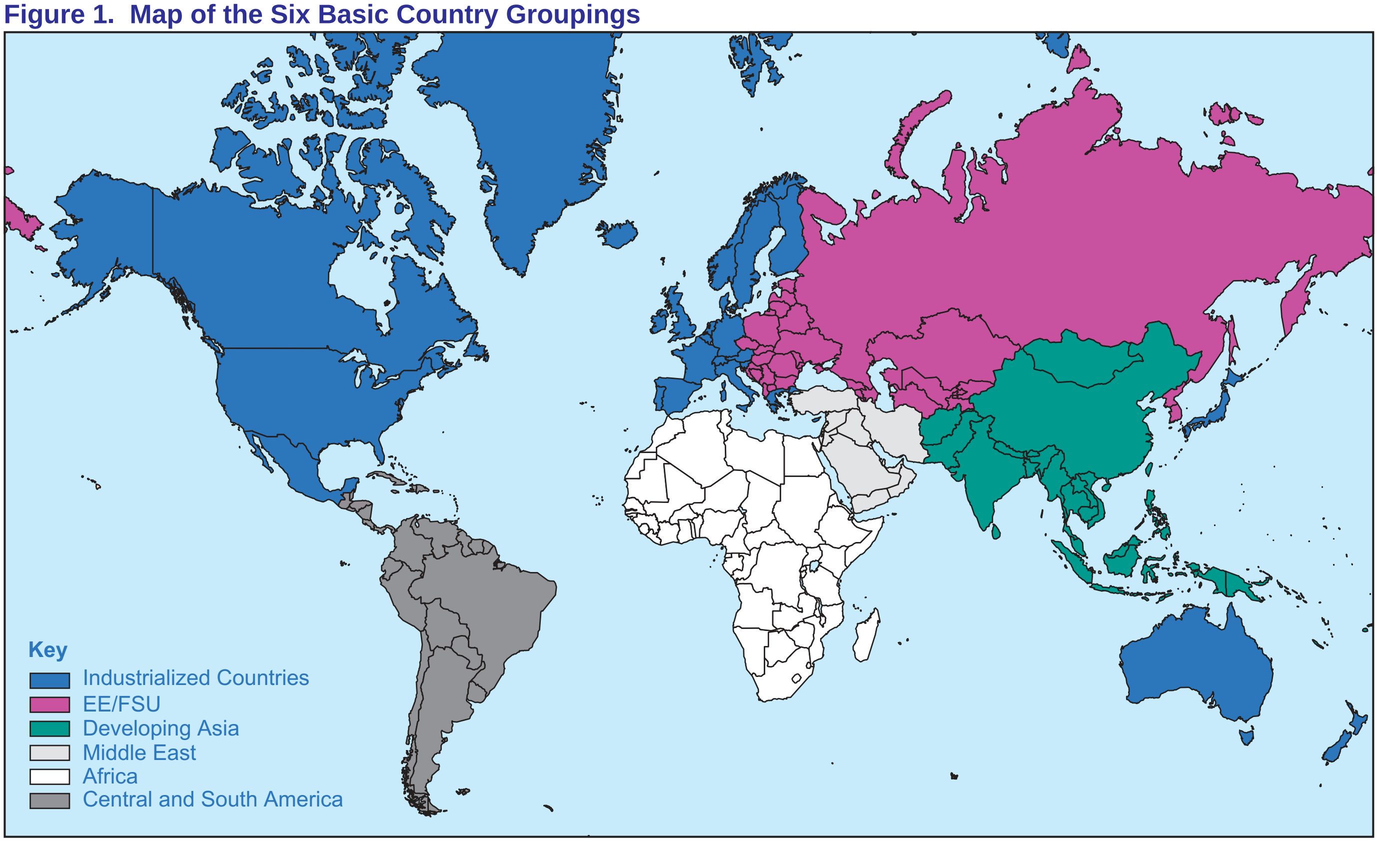
Appendix A contains summary tables of the *IEO2003* reference case projections for world energy consumption, gross domestic product (GDP), energy consumption by fuel, electricity consumption, carbon emissions, nuclear generating capacity, energy consumption measured in oil-equivalent units, and regional population growth. The reference case projections of total foreign energy consumption and consumption of 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 emissions. In addition, the National Energy Modeling System's (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 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 2003 world population): Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and the United States.
- **Eastern Europe and the Former Soviet Union (EE/FSU)** (6 percent of the 2003 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 2003 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 2003 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 2003 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 2003 world population): Antarctica, Antigua and Barbuda, Argentina, Aruba, Bahama Islands, Barbados, Belize, Bolivia, Brazil, British Virgin Islands, Cayman Islands, Chile, Colombia, Costa

Figure 1. Map of the Six Basic Country Groupings



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

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, 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 *IEO2003* Projections

The projections in *IEO2003* 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 policies effective as of October 1, 2002. Assuming fixed policies, even knowing that changes will occur, will naturally result in projections that differ from the final data.

Models are abstractions of energy production and consumption activities, regulatory activities, and producer and consumer behavior. The forecasts are highly dependent on the data, analytical methodologies, model structures, and specific assumptions used in their development. Trends depicted in the analysis are indicative of tendencies in the real world rather than representations of specific real-world outcomes. Even where trends are stable and well understood, the projections are subject to uncertainty. Many events that shape energy markets are random and cannot be anticipated, and assumptions concerning future technology characteristics, demographics, and resource availability cannot be known with 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 58 percent from 2001 to 2025. Much of the growth in worldwide energy use is expected in the developing world in the IEO2003 reference case forecast.

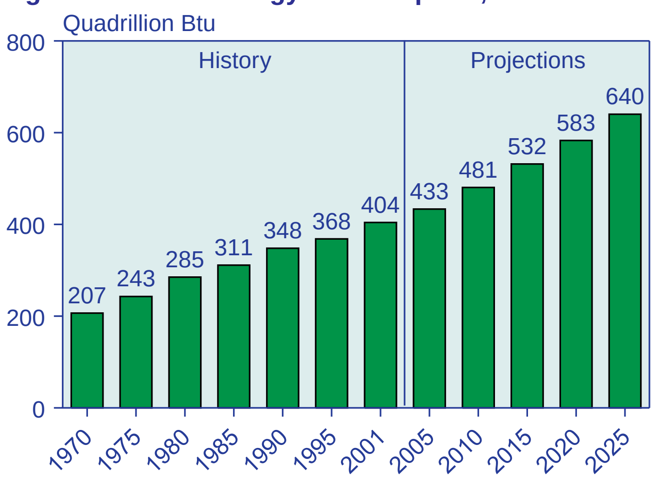
In the *International Energy Outlook 2003* (*IEO2003*) reference case, world energy consumption is projected to increase by 58 percent over a 24-year forecast horizon, from 2001 to 2025. Worldwide, total energy use is projected to grow from 404 quadrillion British thermal units (Btu) in 2001 to 640 quadrillion Btu in 2025 (Figure 2).

As in past editions of this report, the *IEO2003* reference case outlook continues to show robust growth in energy consumption among the developing nations of the world (Figure 3). The strongest growth is projected for developing Asia, where demand for energy is expected to more than double over the forecast period. An average annual growth rate of 3 percent is projected for energy use in developing Asia, accounting for nearly 40 percent of the total projected increment in world energy consumption and 69 percent of the increment for the developing world alone.

Expectations for growth in Central and South America have been lowered substantially from those reflected in last year's report. Political and economic problems surfacing among the nations of the region in the past year have tempered the previously optimistic mid-term outlook for their development. There is continuing unrest in Venezuela; the Argentine economy remains in crisis; the Colombian government has recently renewed an aggressive campaign against insurgency groups; and there is growing dissatisfaction with the Toledo government in Peru. The uncertainties associated with these developments have led to lower projections for the region's energy demand in the *IEO2003* forecast. Whereas energy demand in Central and South America was projected to grow by 3.8 percent per year between 1999 and 2020 in last year's report, the *IEO2003* reference case projects average annual growth of only 2.4 percent from 1999 through 2020 (Figure 4).

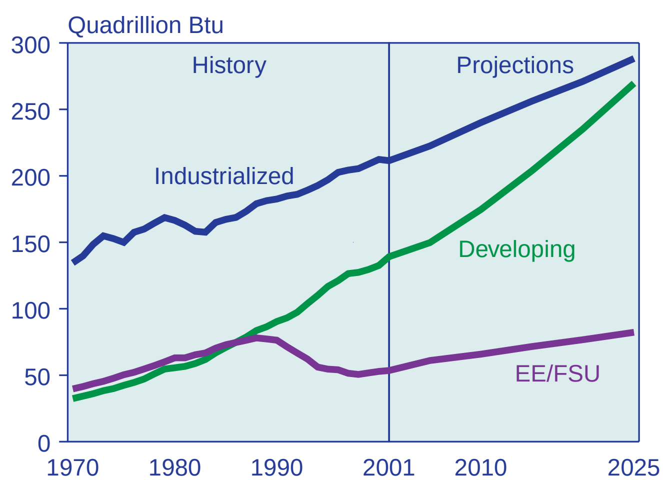
The *IEO2003* reference case expects world oil prices to remain high and volatile throughout 2003, largely because of the abnormally high stock builds that would be needed to bring oil markets back into balance following the disruption in Venezuelan and Iraqi exports. After 2004, prices are expected to return to the mid-term price trajectory anticipated in last year's outlook (Figure 5). World oil prices are projected to reach $27 per barrel in 2001 dollars ($48 per barrel in nominal dollars) at the end of the projection period.

Figure 2. World 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 (2003).

Figure 3. 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 (2003).

Outlook for World Energy Demand

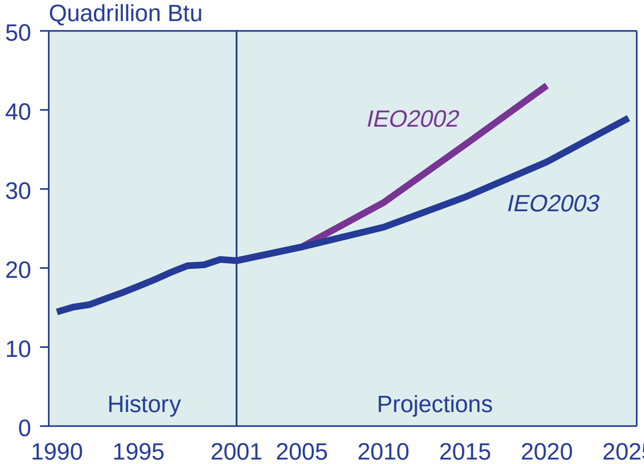
Much of the industrialized world remained in an economic slowdown in 2002. Growth in the United States was hindered by high world oil prices and several large corporate scandals that shook consumer confidence. The sluggish U.S. economy, in turn, had an adverse impact on many global markets that depend heavily on exports to the United States. The mid-term forecast assumes that growth in gross domestic product (GDP) and energy demand will rebound toward the trend projected in last year's outlook. The *IEO2003* reference case projects 1.3-percent average annual growth for energy consumption in the industrialized world between 2001 and 2025, similar to growth rate projected in last year's report.

In the *IEO2003* reference case, world oil consumption is projected to increase by 1.8 percent annually over the 24-year projection period, from 77 million barrels per day in 2001 to 119 million barrels per day in 2025. The projected increases in worldwide oil use would require an increment of a little more than 42 million barrels per day over current productive capacity. OPEC producers are expected to be the major beneficiaries of increased production requirements, but non-OPEC supply is expected to remain competitive, with major increments of supply coming from offshore resources, especially in the Caspian Basin, Latin America, and deepwater West Africa. Deepwater exploration and development initiatives are generally expected to be sustained worldwide, and the offshore Atlantic Basin is expected to emerge as a major source of oil production in both Latin America and 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 drops only slightly in the forecast, from 39 percent in 2001 to 38 percent in 2025, 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 next 24 years. 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.

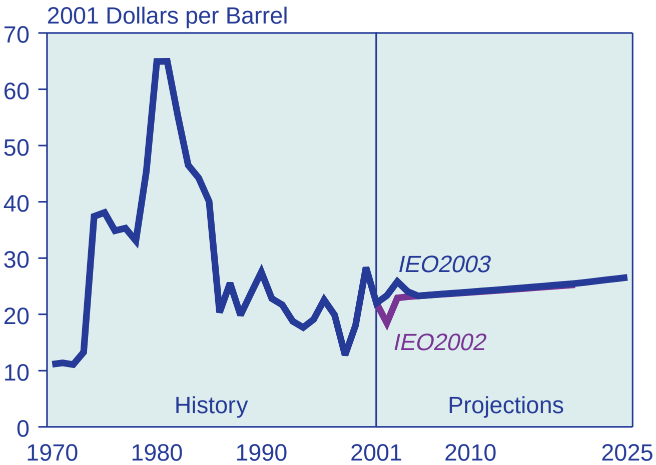
Although the nations of the industrialized world continue to consume more of the world's petroleum products than do those of the developing world, the gap is projected to narrow considerably over the forecast period. In 2001, developing nations consumed about two-thirds (64 percent) as much oil as the industrialized nations; by 2025 they are expected to consume around 86 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

Figure 4. Comparison of 2002 and 2003 Projections for Energy Consumption in Central and South America, 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/. ***IEO2002:*** EIA, *International Energy Outlook 2002*, DOE/EIA-0484(2002) (Washington, DC, March 2002), web site www.eia.doe.gov/oiaf/ieo/index.html. ***IEO2003:*** EIA, System for the Analysis of Global Energy Markets (2003).

Figure 5. Comparison of 2002 and 2003 World Oil Price Projections, 1970-2025



Sources: **History:** Energy Information Administration (EIA), *Annual Energy Review 2001*, DOE/EIA-0384(2001) (Washington, DC, November 2002), web site www.eia.doe.gov/emeu/aer/contents.html. ***IEO2002:*** EIA, *International Energy Outlook 2002*, DOE/EIA-0484(2002) (Washington, DC, March 2002), web site www.eia.doe.gov/oiaf/ieo/index.html. ***IEO2003:*** EIA, *Annual Energy Outlook 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), web site www.eia.doe.gov/oiaf/aeo/index.html.

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 electricity, and industrial demand for petrochemical feedstocks is increasing.

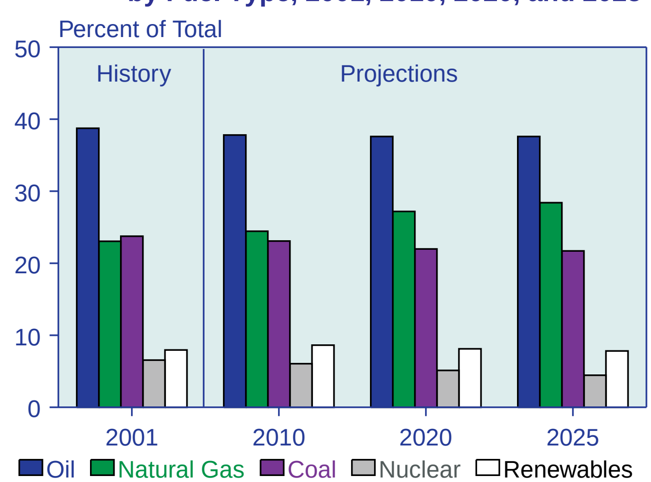
The fastest growing source of primary energy in the *IEO2003* reference case is projected to be natural gas. Over the 2001-2025 forecast period, consumption of natural gas is projected to nearly double in the reference case, to 176 trillion cubic feet in 2025. Natural gas use is expected to surpass coal use (on a Btu basis) by 2005, and by 2025 it is expected to exceed coal use by 31 percent (Figure 7). The natural gas share of total energy consumption is projected to increase from 23 percent in 2001 to 28 percent in 2025, and natural gas is expected to account for the largest increment in electricity generation (increasing by 41 quadrillion Btu and accounting for 53 percent of the total increment in energy use for electricity generation). Much of the projected growth in natural gas consumption throughout the world is in response to rising demand for natural gas to fuel efficient new gas turbine power plants.

In the industrialized world, natural gas is expected to make a greater contribution to incremental energy consumption among the major fuels, increasingly becoming the fuel of choice for new power generation capacity because of its environmental and economic advantages. In the developing countries, increments in natural gas use are expected to supply both power generation and industrial uses. The *IEO2003* reference case projects strong growth in natural gas use in the developing world—averaging 3.9 percent per year between 2001 and 2025—reflecting the growing popularity of the fuel as well as the expectation that the relatively immature gas markets of emerging countries will develop quickly in the coming years.

World coal use has been in a period of generally slow growth since the 1980s, and the trend is expected to continue through the projection period. The projected slow growth in coal consumption, averaging 1.5 percent per year through 2025, suggests that coal will account for a shrinking share of world energy consumption. In the *IEO2003* reference case, the coal share of total energy consumption is projected to fall from 24 percent in 2001 to 22 percent by 2025. Substantial declines in coal use are projected for Western Europe and the EE/FSU countries, where natural gas (and in the case of France, nuclear power) is increasingly being used for electricity generation and for other uses in the industrial and buildings sectors. The expected decline in coal's share of energy use would be even greater were it not for projected large increases in coal use in developing Asia, especially in China and India, where coal continues to dominate many fuel markets. 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 75 percent of the total expected increase in coal use worldwide (on a Btu basis).

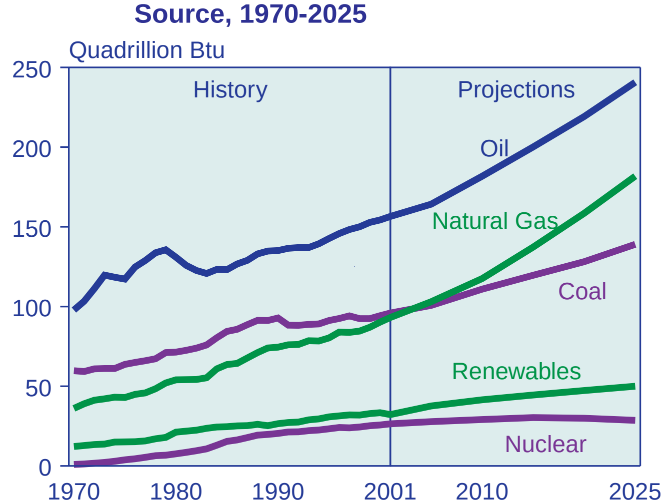
Almost 55 percent of the coal consumed worldwide is used for electricity generation, and its role in the future is expected to be primarily as a fuel for power generation and secondarily as an energy source in a few key industrial sectors, such as steelmaking. Where coal is used in the industrial, residential, and commercial sectors, other energy sources—primarily, natural gas—are expected to

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 (2003).

Figure 7. World 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 (2003).

gain market share. One exception is China, where coal continues to be the most widely used fuel in the country's rapidly growing industrial sector, reflecting the China'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.

Nuclear power accounted for 19 percent of the world's total electricity supply in 2001. The *IEO2003* reference case projects a drop in the nuclear share of electricity, to 12 percent by 2025, as the current trend away from nuclear power in most countries continues. Although some nations are expected to construct new nuclear power plants during the forecast period, declines in nuclear capacity are projected for most of the countries with active nuclear power programs as older plants are retired. The economics of nuclear generating capacity generally compare unfavorably with other available technologies, and public concerns about plant safety, radioactive waste disposal, and weapons proliferation are expected to contribute to the decline of nuclear power in the long term.

Despite its declining share of global electricity production in the *IEO2003* reference case forecast, nuclear power will continue to be a significant source of electricity. Life extensions, higher capacity factors, and capacity uprates are expected to offset some of the capacity losses resulting from retirements. Further, some nations still are expected to continue building new units. Most future capacity additions are expected in Asia, with China, India, Japan, and South Korea projected to add a combined 45 gigawatts between 2001 and 2025. As of February 2003, the nations of developing Asia accounted for 17 of the 35 nuclear reactors under construction worldwide, including 8 in India, 4 in China, 2 each in South Korea and Taiwan, and 1 in North Korea.

Consumption of hydroelectricity and other renewable resources is projected to increase only moderately in the *IEO2003* reference case, at an average annual rate of 1.9 percent per year between 2001 and 2025. Renewable energy sources are not expected to be economically competitive with fossil fuels in the mid-term without significant support from government policies that would encourage their widespread expansion. Much of the growth in use of renewable energy is expected to result from the operation of new large-scale hydroelectric facilities in the developing world, particularly in developing Asia. Among other nations in the region, China, India, Malaysia, and Vietnam are currently constructing or planning large-scale hydroelectric projects. The first electricity generating units of China's 18,200-megawatt Three Gorges Dam project are scheduled to be installed in 2003; India is set to begin the final phase of reservoir filling for its 2,000-megawatt Tehri dam; and Malaysia has awarded the main construction contract for its 2,400-megawatt Bakun dam.

Over the projection period, worldwide net electricity consumption is projected to increase at an average annual rate of 2.4 percent, from 13.9 trillion kilowatthours in 2001 to 24.7 trillion kilowatthours in 2025. Strong growth in electricity use is expected in the countries of the developing world, particularly developing Asia, where robust economic growth is projected to support increased demand for electricity to run newly purchased home appliances for air conditioning, refrigeration, cooking, and space and water heating. China's electricity consumption is projected to nearly triple, growing by an average of 4.3 percent per year in the reference case. Slower growth in population and economic activity, as well as market saturation and efficiency gains for some electronic appliances, is expected to result in a more modest growth rate for electricity use in the industrialized world, at 1.7 percent per year.

International investments in the electricity sector have changed course to some extent in recent years. First, much of the massive U.S. investment in foreign electricity ventures that began in the mid- to late 1990s—particularly in South America, Western Europe, and Australia—has slowed, in part because of the sluggish state of the global economy but also because of disappointing financial performance of many acquisitions. Foreign direct investment in the electricity sectors of the developing world has slowed as well, and the level of such activity in 2001 was only about one-fifth of the 1997 peak level. Mergers and acquisitions among U.S. electricity firms have also slowed substantially since peaking in 1999. Finally, the move toward electricity market restructuring—another trend that flourished in the 1990s—is also changing. Although some countries, including South Korea and Mexico, still are pursuing restructuring programs, others have delayed or modified their restructuring plans. For example, the United Kingdom has reformed its electricity pool in response to evidence of market manipulation, and in Ontario, Canada, a program of electricity price decontrol was reversed after a weather-related spike in retail prices in the summer of 2002.

Carbon Dioxide Emissions

Because estimates indicate that approximately 80 percent of all human-caused carbon dioxide emissions currently come from fossil fuel combustion, world energy use has emerged at the center of the climate change debate. In the *IEO2003* reference case, world carbon dioxide emissions are projected to rise from 6.5 billion metric tons carbon equivalent in 2001 to 7.7 billion metric tons in 2010 and 10.4 billion metric tons in 2025 (Figure 8). 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 59 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 the change 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 *IEO2003* forecast, energy intensity in the industrialized countries is expected to improve (decrease) by 1.3 percent per year between 2001 and 2025, slightly slower than the 1.4 percent per year improvement observed in the region between 1970 and 2001. Energy intensity is expected to improve more rapidly in the developing countries—by 1.7 percent per year on average—as their economies begin to behave more like those of the industrialized countries as a result of improving standards of living that accompany the projected economic expansion (Figure 10).

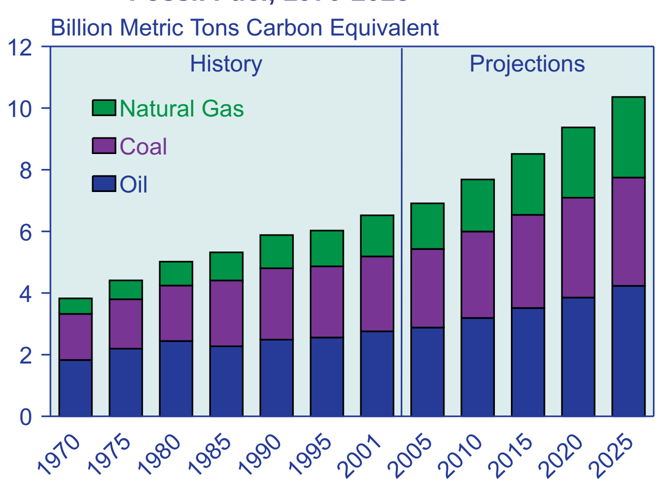
For more than three decades, the EE/FSU has maintained a much higher level of energy intensity than either the industrialized or developing countries. Over the forecast horizon the region's energy intensity is expected to improve—by 2.1 percent per year on average—in concert with expected recovery from 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 Intensity

World carbon intensity has improved (decreased) substantially over the past three decades, falling from 302 metric tons per million 1997 dollars of GDP in 1970 to 202 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 154 metric tons per million 1997 dollars of GDP in 2025.

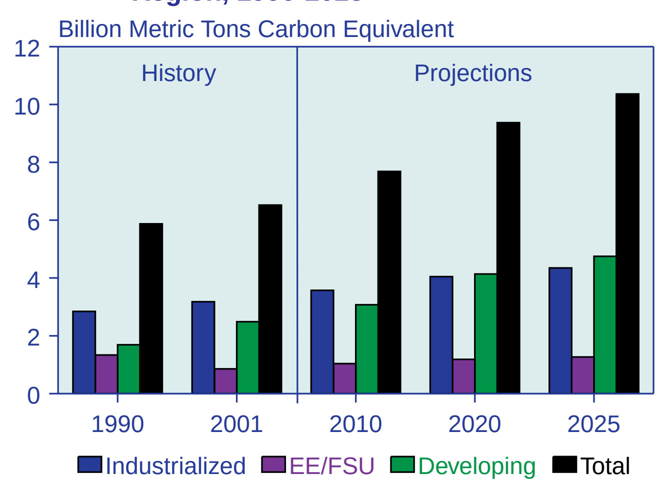
On a regional basis, the most rapid rates of improvement in carbon intensity are projected for the transitional economies of the EE/FSU and the developing Asian countries of China and India. In the FSU, economic recovery from the upheaval of the 1990s is expected to continue throughout the forecast. The FSU nations are also expected to replace old and inefficient capital stock and increasingly use less carbon-intensive natural gas for new electricity generation capacity and for other end

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 (2003).

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



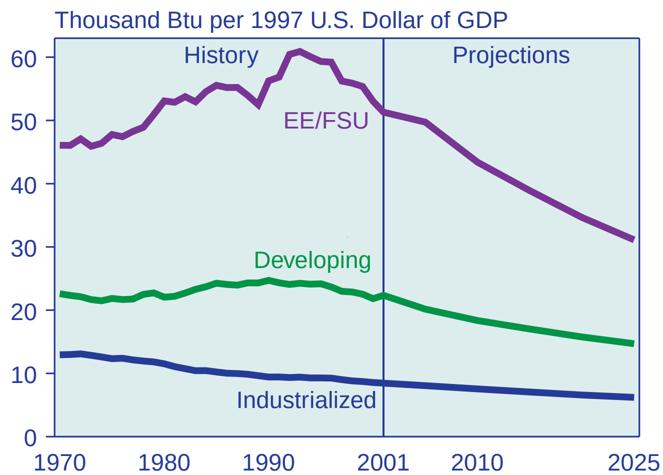
Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2003).

uses rather than more carbon-intensive oil or coal. Eastern European nations have been in economic recovery longer than has the FSU, and natural gas is expected to continue to displace coal use in the region, resulting in an average 2.8-percent annual improvement (decrease) in carbon intensity for Eastern Europe as a whole (Figure 11).

In developing Asia, fairly rapid improvements in carbon intensity are projected for China and India, primarily as a result of rapid economic growth rather than a switch to less carbon-intensive fuels. Both China and India are projected to remain heavily dependent on fossil fuels, particularly coal, in the *IEO2003* reference case, but their annual GDP growth is projected to average 5.9 percent, compared with an expected 3.4-percent annual rate of increase in fossil fuel use from 2001 to 2025.

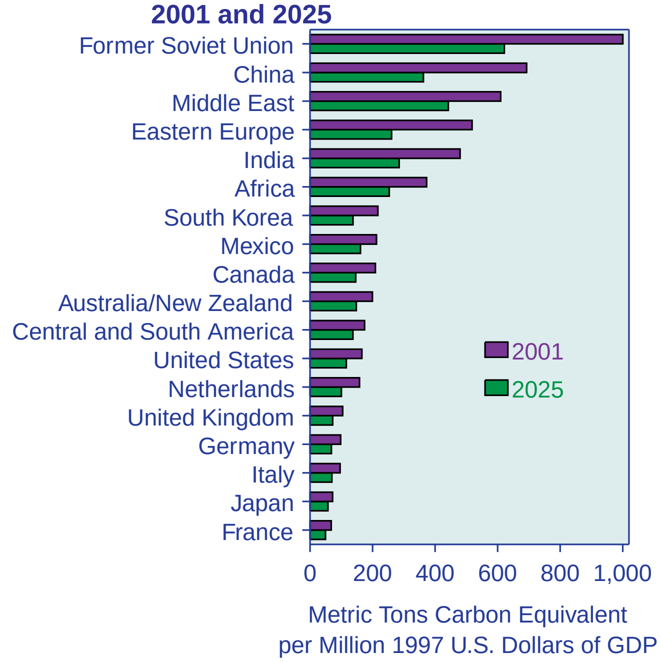
The rate of improvement in carbon dioxide intensity could vary considerably in the future. Technological advances and government policy initiatives have the potential to affect the rate of improvement in carbon intensity, and different rates of economic improvement could also considerably alter future carbon intensity levels. In the *IEO2003* reference case, world carbon dioxide intensity is projected to fall from 202 metric tons carbon equivalent per million 1997 dollars of GDP in 2001 to 154 metric tons per million dollars in 2025; however, if world economic growth expanded to the levels projected in the high economic growth case, carbon dioxide intensity could fall more quickly, to 142 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 166 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 (2003).

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 (2003).

World Energy Consumption

The IEO2003 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 outlook presented in the *International Energy Outlook 2003* (*IEO2003*) shows continuing strong growth for worldwide energy demand over the next 24 years. Total world energy consumption is expected to expand by 58 percent between 2001 and 2025, from 404 quadrillion British thermal units (Btu) in 2001 to 640 quadrillion Btu in 2025 (Table 1 and Figure 12). Overall, the global economy did not perform strongly in 2002. Growth in U.S. markets was hindered by several large corporate scandals and by relatively high world oil prices, and the slow U.S. economy had negative impacts on many global markets that rely heavily on exports to the United States. Nevertheless, the *IEO2003* mid-term outlook continues to show robust growth in energy consumption among the developing nations of the world (Figure 13), particularly in developing Asia (including China and India), where demand for energy is expected to more than double over the next quarter century.

This chapter begins with an overview of current economic trends that are influencing short-term energy markets, followed by a presentation of the *IEO2003* outlook for energy consumption by primary energy source and a discussion of projections for world carbon dioxide emissions resulting from the combustion of fossil fuels. Uncertainty in the forecast is highlighted by an examination of alternative assumptions about economic growth and their impacts on the *IEO2003* projections, and how future trends in energy intensity could influence the reference case projections. Next, a comparison of *IEO2003* projections with forecasts available from other organizations is presented. The chapter ends with an examination of the performance of past *IEO* forecasts for the years 1990, 1995, and 2000.

World Economic Status

The global economy faltered at the end of 2002, and the United States managed a meager 1-percent annualized growth in the fourth quarter. U.S. stock markets felt the impact of a crisis of consumer confidence following several large corporate scandals in 2002. The weak performance of the U.S. economy in 2002 was felt in world markets as well. The United States is the world's largest economy, and many developing nations are largely dependent on exports to the United States to support their own economic expansion. Worldwide, economic growth is expected to recover over the short term, and in the *IEO2003* reference case, world gross domestic product (GDP) is projected to expand by an average of 3.1 percent per year over the 2001 to 2025 forecast period (Table 2).

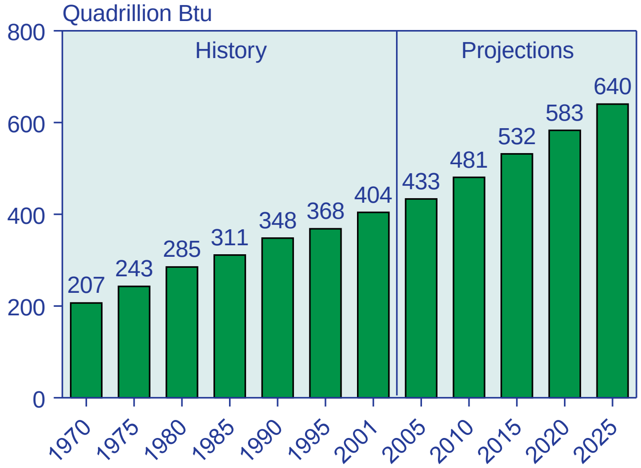
Continuing unrest in the Middle East, the war in Iraq, and a crippling strike in Venezuela aiming to oust President Hugo Chavez all helped to keep oil prices high through much of the past year and into 2003. The Organization of Petroleum Exporting Countries (OPEC) has managed markets to keep the basket oil price above $22 per barrel (nominal) since March 8, 2002 (Figure 14) [***1***].

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

Region	Energy Consumption (Quadrillion Btu)				Carbon Dioxide Emissions (Million Metric Tons Carbon Equivalent)			
	1990	2001	2010	2025	1990	2001	2010	2025
Industrialized Countries	**182.8**	**211.5**	**240.1**	**288.3**	**2,844**	**3,179**	**3,572**	**4,346**
EE/FSU	**76.3**	**53.3**	**65.9**	**82.3**	**1,337**	**856**	**1,038**	**1,267**
Developing Countries	**89.3**	**139.2**	**174.7**	**269.6**	**1,691**	**2,487**	**3,075**	**4,749**
Asia	52.5	85.0	110.1	174.6	1,089	1,640	2,075	3,263
Middle East	13.1	20.8	25.0	36.0	231	354	420	601
Africa	9.3	12.4	14.4	20.0	179	230	261	361
Central and South America	14.4	20.9	25.2	39.0	192	263	319	523
Total World	**348.4**	**403.9**	**480.6**	**640.1**	**5,872**	**6,522**	**7,685**	**10,361**

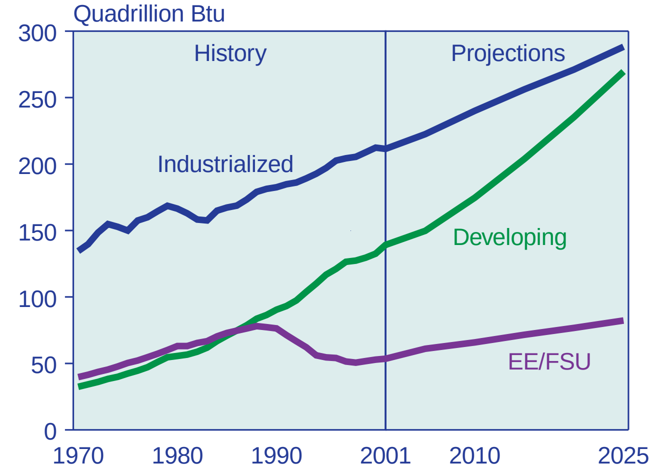
Sources: **1990 and 2001:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **2010 and 2025:** EIA, System for the Analysis of Global Energy Markets (2003).

Figure 12. World 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 (2003).

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 (2003).

Table 2. World Gross Domestic Product by Selected Countries and Regions, 1970-2025
(Billion 1997 U.S. Dollars)

Region	History			Projections				Average Annual Percent Change	
	1970	1990	2001	2010	2015	2020	2025	1970-2001	2001-2025
Industrialized Countries									
North America	4,068	7,723	10,588	14,192	16,645	19,246	22,218	3.1	3.1
United States	3,646	6,836	9,394	12,497	14,566	16,770	19,285	3.1	3.0
Canada	276	555	742	978	1,112	1,253	1,406	3.2	2.7
Mexico	145	332	452	717	967	1,223	1,528	3.7	5.2
Western Europe	4,506	7,597	9,460	11,694	13,125	14,724	16,395	2.4	2.3
France	751	1,299	1,593	1,974	2,214	2,497	2,781	2.5	2.3
Germany	1,149	1,879	2,274	2,780	3,100	3,450	3,811	2.2	2.2
Industrialized Asia	1,815	4,054	4,920	5,891	6,512	7,153	7,828	3.3	2.0
Japan	1,608	3,673	4,376	5,164	5,662	6,162	6,680	3.3	1.8
EE/FSU									
Former Soviet Union	625	1,009	654	957	1,152	1,360	1,600	0.1	3.8
Eastern Europe	236	348	390	561	689	853	1,044	1.6	4.2
Developing Countries									
Asia	472	1,739	3,525	5,856	7,528	9,513	11,752	6.7	5.1
China	106	427	1,201	2,191	2,949	3,935	5,085	8.2	6.2
India	113	268	521	832	1,077	1,390	1,775	5.1	5.2
Middle East	172	379	581	808	970	1,154	1,359	4.0	3.6
Africa	206	405	617	862	1,027	1,216	1,426	3.6	3.6
Central and South America	586	1,136	1,505	1,983	2,446	3,040	3,811	3.1	3.9
Total World	**12,687**	**24,392**	**32,239**	**42,804**	**50,095**	**58,259**	**67,434**	**3.1**	**3.1**

Sources: Global Insight, Inc., *World Economic Outlook*, Vol. 1 (Lexington, MA, Third Quarter 2002), and Energy Information Administration, System for the Analysis of Global Energy Markets (2003).

High world oil prices have the potential to further dampen economic expansion. The weakness of U.S. consumer demand—which has supported economic growth for some time—is matched by likely economic declines in Japan and stagnation in the European Union (EU). Another below-trend performance is expected for the world economy in 2003 before recovery in 2004.

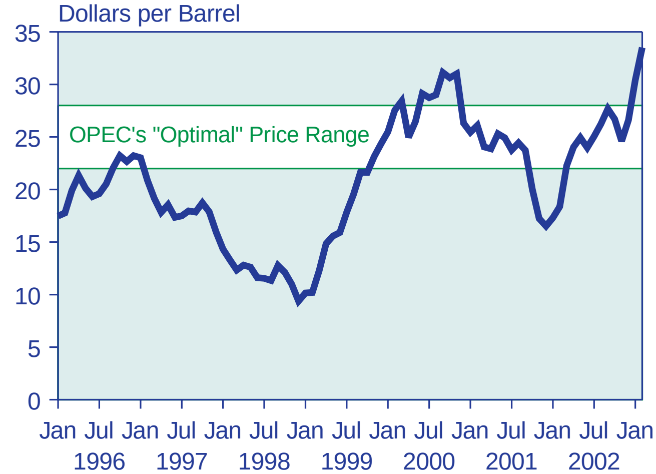
Industrialized World

The U.S. economy has suffered a number of setbacks in the past 3 years, including the terrorist attacks of September 2001, the significant loss of stock market wealth since 2000, and recent corporate accounting scandals, including U.S. energy company Enron and telecommunications company WorldCom Group [***2***]. Yet the recession of 2001 was one of the mildest on record, with recovery proceeding slowly in 2002. The recovery—attributed to continuing consumer spending, a strong housing market, and activist fiscal and monetary policies—has been slowed by falling consumer confidence, high oil prices, and war jitters. Debates over another government fiscal stimulus have just begun, but the eventual outcome may well provide a significant boost to the U.S. economy in 2003. U.S. GDP is projected to grow at an average annual rate of 3.0 percent per year from 2001 to 2025.

Canada's economy continued to outperform expectations in 2002. GDP growth in Canada exceeded that in the United States between 1999 and 2002, and in 2002 Canada recorded the strongest growth among the G-8 nations [***3***]. Housing starts, automobile sales, strong government spending, and a robust energy sector were leading contributors to Canada's economic growth. Although the pace of the country's growth did slow in conjunction with the general worldwide economic slowdown in 2002, it is expected to improve along with a recovery in the United States. Canada's economic growth rate is projected to average 2.7 percent per year over the projection period.

Mexico—which along with Canada is a U.S. partner in the North American Free Trade Agreement (NAFTA)—also returned to positive growth in 2002. High world oil prices helped Mexico avoid a substantial dip in GDP expansion in 2001 and allowed the country to achieve its 2002 fiscal deficit target of 0.65 percent of GDP [***4***]. In general, many analysts believe that the United States will cushion Mexico from the economic troubles that have hampered other countries in Latin America, and Mexico's GDP is expected to expand by a robust 5.2 percent per year on average over the next 24 years. Mexico is, however, more dependent on U.S. growth than are the other Latin American countries. The Fox Administration has announced plans to limit public spending in its 2003 budget because of fears that the U.S. recovery may be more prolonged than was expected in 2002 [***5***].

Figure 14. Refiner Acquisition Cost of Imported Crude Oil, 1996-2002



Source: Energy Information Administration, *Monthly Energy Review*, DOE/EIA-0035(2003/04) (Washington, DC, April 2003).

Economic performance in other industrialized regions of the world has been equally or more lackluster. In Germany, Western Europe's largest economy, economic performance was anemic throughout 2002. The German government had few options for stimulus: the European Central Bank has been reluctant to cut EU interest rates to stimulate economic growth, and Germany is constrained from carrying out any fiscal policy changes because of the weak state of public finances and limits placed on the government by the EU's Stability and Growth Pact, which requires that EU member countries maintain deficits that do not exceed 3 percent of GDP in any single year [***6***]. The European Commission issued a warning to Germany on its breach of the deficit limit, threatening punishment if it did not take action to reduce its deficit before May 21, 2003 [***7***].

High unemployment and the costs associated with recovering from a devastating flood in the summer of 2002 have led the German government to delay a tax cut scheduled for January 2003, leading many analysts to believe that chances for a near-term economic recovery are remote [***8***]. In December, the European Central Bank moved to cut its benchmark interest rate by 0.5 percentage point, the first cut since November 2001, citing a lackluster "overall sentiment in the economy" [***9***]. The Bank stated that it was able to cut interest rates without fear of inflation because of the protracted sluggishness of economic growth among the EU member countries. Critics of the Bank's hesitancy to cut rates over the past year argue that the impact of the November interest rate cut may not be felt in Europe for up to a year, and that Germany, as well as France and Italy, may fall into recession in the meantime.

In Japan, the world's second largest economy continued to contract in 2002. After a decade of fiscal erosion, spiraling private debt, and price deflation, the country found itself in a position of acute vulnerability to any external shock. The government of prime minister Junichiro Koizumi has had only limited success in getting economic reforms passed in the Japanese Diet. Compromise postal reform bills were passed in June 2002, allowing a shift of the national postal service and its financial functions into a private corporation [**10**]. Koizumi is also attempting to shift fiscal policy away from government stimulus packages (implemented through public works) toward a tax cut.

In late September 2002, Koizumi announced a reshuffling of his cabinet, replacing his chief financial regulator, Hakuo Yanagisawa, with Heizo Takenaka, who is known to be a strong proponent of reform [**11**]. Mr. Takenaka has been assigned the roll of "economy czar" and has been charged with the task of cleaning up commercial banks that have accumulated an estimated $423 billion in bad loans over the past 12 years. It is difficult to assess how successful Takenaka may be, and for the near-term future the Japanese economy is expected to continue only tepid performance. GDP in Japan is projected to grow by only 1.8 percent per year between 2001 and 2025, substantially lower than its 3.3-percent average over the past 30 years.

Central and South America

In 2002, substantial political and economic troubles arose among the nations of Central and South America. Uncertainties among the nations of the region include prospects for national elections in several large countries that may well change the political landscape, the continuing economic crisis in Argentina, political unrest in Venezuela, a renewed aggressive campaign against insurgency groups in Colombia, and mounting popular dissatisfaction with the Toledo government in Peru. As a result, projections for the region's economic growth have been lowered in *IEO2003*, along with expectations for increments in energy demand. Whereas last year's report (*IEO2002*) projected 4.5-percent average annual growth in GDP in Central and South America from 1999 to 2020, *IEO2003* projects only 3.6-percent annual growth for the same time period.

Brazil's economy, the largest in Central and South America, has been hampered by the lingering global economic weakness. Beginning in the second quarter of 2002, industrial production in Brazil began to weaken substantially, and unemployment rates increased precipitously. The Brazilian Central Bank lowered interest rates from 18.5 percent to 18 percent, but the high interest rates compounded the difficulty of achieving economic recovery [**12**]. In mid-October 2002, in an effort to halt the depreciation of the Brazilian real, the Bank increased interest rates to a 3-year high of 21 percent in the hope that high interest rates would make short-term domestic investments more attractive by offering higher returns on domestic bonds [**13**].

Mounting dissatisfaction with the performance of the Brazilian economy fueled public support for the presidential candidacy of Luiz Inácio Lula da Silva, who was elected to the office on October 27, 2002, with 61 percent of the vote—the largest margin of victory by a presidential candidate in the history of the country [**14**]. Many analysts believe that the election of Lula will stall privatization efforts, with policies aimed at reversing the previous administration's move to liberalize many state-owned enterprises.

Fears that the Lula administration might be detrimental to prospects in Brazil are making foreign investors nervous about committing investment funds, making it difficult for the country to manage its $260 billion public debt [**15**]. The Lula administration does not have much fiscal room to maneuver, however, given Brazil's past agreements with the International Monetary Fund (IMF) to hold down public deficits in return for loans and credit. The IMF, apparently believing that Brazil intends to honor its commitments, has approved a request for a 15-month standby credit of $30.4 billion through December 2003, citing the country's "strong and consistent macroeconomic policies in recent years that have improved fundamentals" [**16**].

In Venezuela, the Chavez administration has faced growing discontent among union workers and businessmen as a result of its handling of the economy, particularly in dealings with state-owned Petroleos de Venezuela (PDVSA). When Chavez attempted to replace PDVSA executives with political allies, demonstrations and protests were launched that culminated in an ultimately unsuccessful coup attempt in April 2002 [**17**]. Nevertheless, Chavez declared his intention to fulfill his complete presidential term and stay in office until 2007. Tensions in the country remained high, and a 2-month nationwide strike that began on December 2, 2002, resulted in a pronounced slowdown of operations at PDVSA [**18**]. Oil is the key source of revenue for Venezuela (accounting for some 80 percent of the country's total export revenues). Although world oil prices remained high in 2002, the country still saw a contraction in GDP of almost 10 percent in the second quarter of 2002, and unemployment stood at 16.4 percent. None of these developments bodes well for near-term economic growth in Venezuela.

Argentina, another key economy of the Central and South American region, experienced another disappointing economic year in 2002. After a deteriorating financial situation at the end of 2001 resulted in the rapid succession of five presidents, Eduardo Duhalde assumed the role of interim president in January 2002. The economic situation has not shown much improvement, with real GDP contracting by 12 percent in 2002, and new elections are now scheduled for April 2003 [**19**]. There are hopes that the Argentine economy has begun to stabilize. After a year of negotiations, Argentina was able to secure a $6.8 billion loan package from the IMF in January 2003. Under the terms of the agreement, the IMF has approved a short-term credit line of nearly $3 billion to repay debts to multinational organizations that could not be postponed. It has also extended its deadline for repayment of some $3.8 billion to August 31, 2003. The country faces around $18 billion worth of repayments before the end of 2003.

Developing Asia

For the most part, the nations of developing Asia showed positive economic growth in 2002, and there is cautious optimism that national economies in the region will continue to expand despite slow economic growth in the industrialized world. The two largest economies in the region—China and India—both saw robust GDP growth in 2002, which is expected to continue in the near term. China and India alone are expected to see combined average economic growth of 5.9 percent per year from 2001 to 2025 in the *IEO2003* reference case.

The November 2001 accession of China into the World Trade Organization (WTO) gives analysts some reason for concern in the mid-term. Although WTO membership is expected to advance trading opportunities and a voice in future global economic organization negotiations, there is fear that unemployment may rise with the opening of China's markets to competition, accompanied by the potential for social discord, and that economic growth in the short term will be dampened [**20**]. To counteract the potential negative impacts of WTO membership, the Chinese government plans to increase spending on public works projects, releasing some 150 billion yuan (about $18 billion) in special funds to finance the projects [**21**]. In the mid-term, China will still need to reform overstaffed and inefficient state-owned companies and a banking system that is carrying large nonperforming loans. In 2002, nonperforming loans accounted for 23 percent of total loans, and the government has set a target for state-owned banks to reduce them to 15 percent of the total by 2005 [**22**].

India's economy has also performed well over the past 2 years, with GDP increases of 5.4 percent in 2001 and an estimated 4.8 percent in 2002 [**23**] attributed to strong growth in the manufacturing sector and a robust recovery in the agricultural sector after a 2-year drought. Several legislative moves aimed at improving the country's privatization efforts were passed in 2002, including a July 2002 government announcement that it would allow companies that assume government stakes in businesses to finance the acquisitions through external commercial loans, and the April 2002 abolition of the oil refinery sector's Administered Pricing Mechanism, which is expected to result in greater competition for India's refineries [**24**]. India's Power Minister, Suresh Prabhu, has announced that further legislation will be introduced to end the monopoly of state utilities on electricity distribution, allowing private companies to sell electricity directly to consumers. Analysts hope that the legislation will remove the distribution restrictions that have hampered India's efforts to reform its power sector and attract new foreign investment in the electricity sector [**25**]. Mid-term prospects for India are encouraging as the country continues to privatize state enterprises and increasingly adopts free market policies. In the *IEO2003* reference case, India's GDP is expected to expand by 5.2 percent per year on average between 2001 and 2025.

Economic growth in 2002 was sustained in other countries of developing Asia, with some exceptions. The pillar of economic expansion in the region continues to be consumer demand and exports. Many Asian nations rely on exports to the United States and other industrialized countries for revenues, and the slow economic growth among the nations of the industrialized world has slowed short-term growth in many of the region's developing countries. In particular, electronics exporting countries like Singapore, South Korea, and Taiwan are hoping that a recovery in demand for computer equipment and other electronics in the United States, Japan, and Western Europe will spur their GDP growth in 2003 [**26**].

Eastern Europe and the Former Soviet Union

Positive GDP growth continued in the transitional economies of the former Soviet Union (FSU) in 2002 but at slower rates than the near double-digit increases that were reported among the region's countries in 2000 and 2001. After the dissolution of the Soviet Union in the early 1990s, the region's GDP fell to $545 billion (1997 dollars) in 1998, lower than its 1970 level. The FSU region is expected to sustain positive economic growth between 2001 and 2025, with a projected average GDP growth rate of 3.8 percent per year in the *IEO2003* reference case.

Positive economic growth only returned to the FSU in 1999, when high world oil prices and a devalued ruble helped Russia, the region's largest economy, post strong economic gains by boosting performance in its industrial sector and increasing consumer demand for domestically produced goods. In 2002, the Russian ruble continued to gather strength, making it possible for foreign goods to compete with domestic supplies. Household income also continued to improve, strengthening domestic consumer demand. High world oil prices have helped to support the Russian economy, but investors have expressed fears that without greater transparency and a legal framework that would protect foreign investors, such as production sharing agreements for the energy sector, it will be difficult to attract the levels of foreign financial investment needed to support continued advances in Russia and many of the other former Soviet Republics [***27***].

As a region, Eastern Europe began to see sustained economic recovery much sooner than did the FSU countries. Most Eastern European countries saw positive GDP growth return by the mid-1990s. 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. Nevertheless, the nations of Eastern Europe are expected to perform modestly well in the near term.

A strong boost for Eastern Europe came in October 2002, when Ireland voted to accept the Nice Treaty, which allows for the expansion of EU membership [***28***]. Ireland is the only EU member that required a national referendum to approve the treaty (it was rejected by the Irish electorate in a previous referendum). Ten countries are to be invited to join the EU in 2004, including the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia, and Slovenia in Eastern Europe, with Bulgaria and Romania to join in 2007. With the accessions expected to begin in 2004, the Eastern European region should begin to benefit from EU membership with increased regional aid, as well as easing of trade restrictions once the EU borders have been expanded. As a result, prospects for the region are expected to remain positive, and its total GDP is projected to expand by an average of 4.2 percent per year through 2025.

Outlook for Primary Energy Consumption

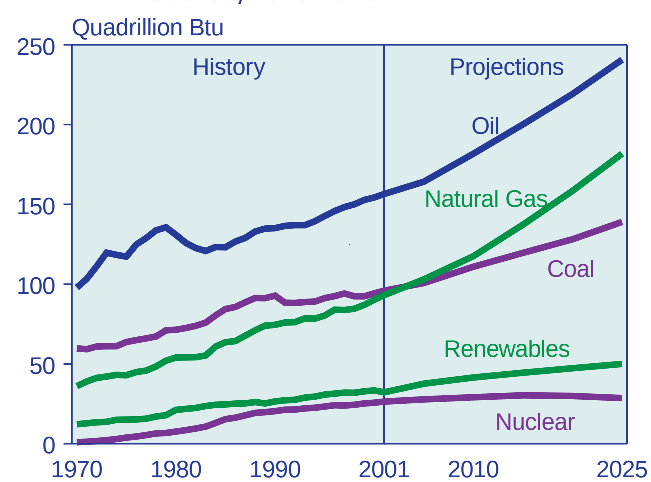
The *IEO2003* reference case projects that consumption of every primary energy source will increase over the 24-year forecast horizon (Figure 15 and Appendix A, Table A2). Much of the increment in future energy demand in the reference case is projected to be for fossil fuels (oil, natural gas, and coal), because it is expected that fossil fuel prices will remain relatively low, and that the cost of generating energy from other fuels will not be competitive. It is possible, however, that as environmental programs or government policies—particularly those designed to limit or reduce greenhouse gas emissions—are implemented, the outlook might change, and non-fossil fuels (including nuclear power and renewable energy sources such as hydroelectricity, geothermal, biomass, solar, and wind power) might become more attractive. The *IEO2003* projections assume that government policies or programs in place as of October 1, 2002, will remain constant 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 falling only slightly from 39 percent in 2001 to 38 percent in 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 *IEO2003* reference case projects declining oil use for electricity generation, with other fuels (especially natural gas) expected to be 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 noncommercial fuels have been widely used in the past (such as fuel wood for cooking and home heating), diesel generators 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 [***29***]. 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 expected to grow in the developing world, but not enough to accommodate all of the increase in demand for energy.

Natural gas is projected to be the fastest growing primary energy source worldwide, maintaining growth of 2.8 percent annually over the 2001-2025 period, nearly twice the rate of growth for coal use. Natural gas consumption is projected to rise from 90 trillion cubic feet in 2001 to 176 trillion cubic feet in 2025, primarily to fuel electricity generation. Gas is increasingly seen as the desired option for electric power, given the efficiency of

Figure 15. World 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 (2003).

combined-cycle gas turbines relative to coal- or oil-fired generation, 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.

Coal use worldwide is projected to increase by 2.2 billion short tons (at a rate of 1.5 percent per year) between 2001 and 2025. Substantial declines in coal use are projected for Western Europe and the EE/FSU countries, 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, even larger increases in coal use are expected. The largest increases are projected for China and India, where coal supplies are plentiful. Together these two countries account for 86 percent of the projected rise in coal use in the developing world over the forecast period.

Worldwide, consumption of electricity generated from nuclear power is expected to increase from 2,521 billion kilowatthours in 2001 to 2,737 billion kilowatthours in 2025. Until very recently, nuclear electricity consumption was expected to decline sharply by the end of the forecast. The prospects for nuclear power have been reassessed, however, 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. Further, 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 many of the industrialized countries, extending the operating life of a nuclear power plant is a decision left primarily to the owner and thus is essentially a question of economic viability. In the *IEO2003* reference case, world nuclear capacity is projected to rise from 353 gigawatts in 2001 to 393 gigawatts in 2015 before falling to 366 gigawatts in 2025 (Figure 16). In contrast, in last year's *IEO*, world nuclear capacity was projected to rise to 363 gigawatts in 2010 and then fall to 359 gigawatts in 2020.

The highest growth in nuclear generation is projected 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. In particular, developing Asia is expected to see the greatest expansion in new nuclear generating capacity. As of February 2003, the nations of developing Asia accounted for 17 of the 35 reactors currently under construction worldwide, including 8 in India, 4 in China, 2 each in South Korea and Taiwan, and 1 in North Korea [***30***], accounting for 12 of the 30 gigawatts currently under construction.

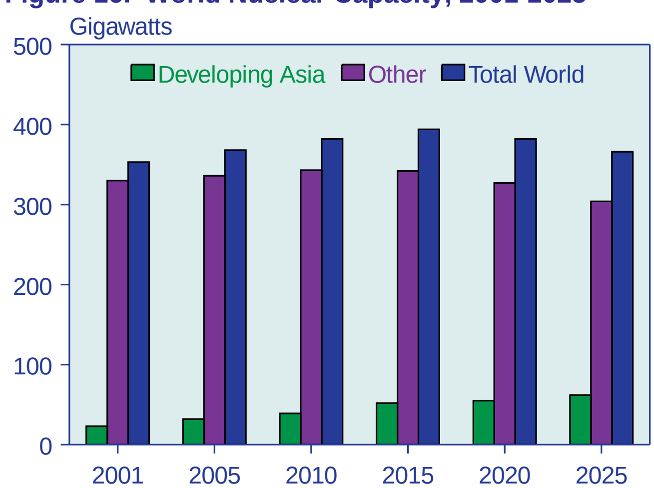
Consumption of electricity from hydropower and other renewable energy sources is projected to grow by 1.9 percent annually in the *IEO2003* forecast. With fossil fuel prices projected to remain relatively low in the reference case, renewable energy sources are not expected to be widely competitive, and 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 biomass and geothermal power in the United States, much of the growth in renewable energy sources will 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 over the projection period.

Outlook for Carbon Dioxide Emissions

World carbon dioxide emissions are expected to increase by 3.8 billion metric tons carbon equivalent over current levels by 2025—growing by 1.9 percent per year—if world energy consumption reaches the levels projected in the *IEO2003* reference case (Figure 17). According to this projection, world carbon dioxide emissions in 2025 would exceed 1990 levels by 76 percent. Oil and natural gas contribute about 1.5 and 1.3 billion metric tons, respectively, to the projected increase from 2001, and coal provides the remaining 1.1 billion metric tons carbon equivalent.

Carbon dioxide emissions from energy use in the industrialized countries are expected to increase by 1.2 billion metric tons carbon equivalent to 4.3 billion metric tons in

Figure 16. World 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 (2003).

2025, or by about 1.3 percent per year (Figure 18). Emissions from the combustion of petroleum products account for more than 44 percent of the total increment expected for the industrialized world, and the increase in emissions from natural gas is expected to be more than twice as large as that from coal.

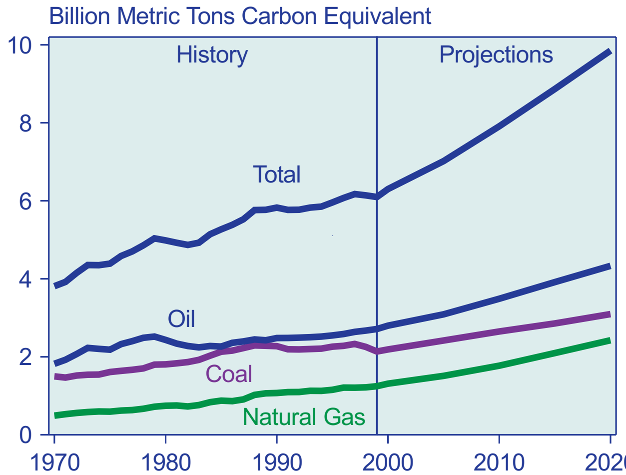
By 2020, carbon dioxide emissions in the developing world (including China and India) are expected to surpass those in the industrialized countries, even though developing countries are projected to use less energy than industrialized countries at that time (Figure 18). Total emissions in developing nations are expected to increase by 2.3 billion metric tons to a total of 4.7 billion metric tons carbon equivalent in 2025, representing about 59 percent of the projected increment worldwide. The sizable rise in emissions among the developing nations is partially a result of their continued heavy reliance on coal, the most carbon-intensive of the fossil fuels. Coal is used extensively in the developing Asia region, which has the highest expected rate of economic and energy growth in the forecast. Carbon dioxide emissions in developing Asia alone are projected to increase from 1.6 billion metric tons carbon equivalent in 2001 to 3.3 billion metric tons in 2025.

In the EE/FSU region as a whole, carbon dioxide emissions are not expected to return to their Soviet-era levels during the projection period. This year's reference case projection has been revised to reflect the expectation that coal use will not decline as precipitously as was projected in previous editions of this report, particularly among the FSU countries. The region 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. 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. The region may also be able to take advantage of its lower emissions levels should a worldwide carbon trading system be enacted in the future.

Worldwide, carbon dioxide emissions per person are projected to increase from about 1.1 metric tons in 1990 to 1.3 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 3.2 to 3.6 metric tons per person between 1990 and 2010 and then to 4.2 metric tons per person in 2025 in the *IEO2003* reference case (Figure 19).

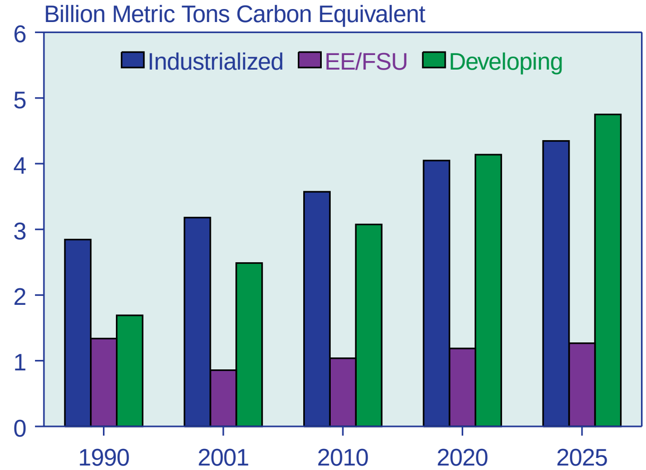
In December 2002 Canada and New Zealand ratified the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) [***31***]. As of February 24, 2003, 104 countries plus the European Community had ratified the treaty. Thirty of the ratifying nations are the so-called Annex I countries, which are required to limit or reduce their greenhouse gases relative to 1990 levels under the terms of the Protocol.[2]

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 (2003).

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 (2003).

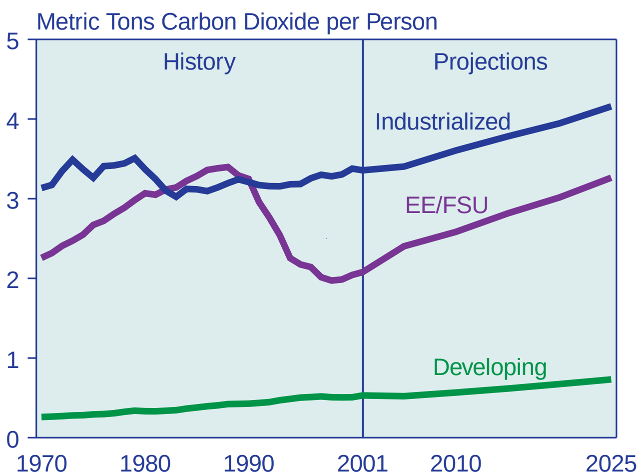
[2]As of February 24, 2003, the following Annex I countries had ratified, accepted, approved or acceded to the Kyoto Protocol: Austria, Belgium, Bulgaria, Canada, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Lithuania, Luxembourg, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom.

These 30 countries accounted for around 44 percent of the total Annex I emissions in 1990. The Kyoto Protocol enters into force 90 days after it has been ratified by at least 55 of the 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. Although the United States had the largest share of Annex I emissions in 1990 at 35 percent, even without U.S. participation the Protocol could enter into force for other signatories. Russia has publicly announced plans to advance ratification of the Kyoto Protocol [***32***]. Because Russia accounted for 17 percent of the 1990 Annex I carbon dioxide emissions, its ratification would bring the Protocol into force as long as Russia meets the Protocol's requirements for verifying and monitoring emissions levels.

China and India also 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 2001.

In the United States, the Bush Administration has introduced initiatives aimed at reducing greenhouse gas intensity as an alternative to the Kyoto Protocol. Under the President's Clear Skies and Global Climate Change Initiatives, the United States will work to reduce greenhouse gas intensity by 18 percent by 2012 [***33***]. Carbon dioxide intensity is defined as the amount of carbon

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 (2003).

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, falling from 302 metric tons carbon equivalent per million 1997 dollars of GDP in 1970 to 202 metric tons per million 1997 dollars in 2001 (Table 3). 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 154 metric tons per million 1997 dollars in 2025.

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 and India. 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 and increasingly use less carbon-intensive natural gas for new electricity generation and other end uses rather than the more carbon-intensive oil and coal. Eastern European nations have been in economic recovery longer than has the FSU, and natural gas is expected to continue to displace coal use in the region, resulting in an average 2.8-percent annual improvement (decrease) in carbon intensity for Eastern Europe as a whole.

In developing Asia, fairly rapid improvements in carbon dioxide intensity are expected for China and India over the projection period, primarily as a result of rapid economic growth rather than a switch to less carbon-intensive fuels. Both China and India are projected to remain heavily dependent on fossil fuels, particularly coal, in the *IEO2003* reference case, but their annual GDP growth is projected to average 5.9 percent, compared with an expected 3.4-percent annual rate of increase in fossil fuel use from 2001 to 2025.

Alternative Growth Cases

A major source of uncertainty in the *IEO2003* forecast is the expected rate of future economic growth. *IEO2003* 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 (Figure 20).

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, one percentage point is added to the reference case GDP growth rates for the high economic growth case and one percentage point is subtracted from the reference case GDP growth rates for the low economic growth case. Outside the industrialized world and excluding China and the EE/FSU, 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.

Because China had particularly high, often double-digit growth in GDP throughout much of the 1990s, it has the potential for a larger downturn in economic growth. In contrast, the EE/FSU region suffered a severe economic collapse in the early part of the decade and has been trying to recover from it with mixed success. The EE/FSU nations have the potential for substantially higher economic growth if their current political and institutional problems moderate sufficiently to allow the recovery of a considerable industrial base. As a result of these uncertainties, 2.5 percentage points are subtracted from the reference case GDP assumptions for China to form the low economic growth case, and 1.0 percentage point is added to the reference case to form the high economic growth case. For the EE/FSU region, 1.0 percentage point is subtracted from the reference case assumptions to derive the low economic growth case, and 2.5 percentage points are added for the high economic growth case.

The *IEO2003* reference case shows total world energy consumption reaching 640 quadrillion Btu in 2025, with the industrialized world projected to consume 288

Table 3. World Carbon Dioxide Intensity by Selected Countries and Regions, 1970-2025
(Metric Tons Carbon Equivalent per Million 1997 U.S. Dollars)

Region	History				Projections				Average Annual Percent Change	
	1970	1980	1990	2001	2005	2010	2020	2025	1970-2001	2001-2025
Industrialized Countries										
North America										
United States	315	258	198	166	154	144	124	116	-2.0	-1.5
Canada	346	297	232	209	203	190	157	146	-1.6	-1.5
Mexico	183	225	253	213	212	193	169	161	+0.5	-1.1
Western Europe										
United Kingdom	223	191	143	104	95	88	77	73	-2.4	-1.5
France	146	132	79	68	61	55	49	48	-2.4	-1.4
Germany	233	194	144	98	90	83	70	67	-2.8	-1.5
Italy	133	120	105	96	89	84	72	67	-1.0	-1.5
Netherlands	213	211	181	158	142	134	111	101	-1.0	-1.9
Industrialized Asia										
Japan	125	105	73	72	69	65	59	57	-1.7	-1.0
Australia/New Zealand	323	216	210	199	189	180	155	148	-1.5	-1.2
EE/FSU										
Former Soviet Union	897	977	1,027	1,000	1,012	862	691	621	+0.4	-2.0
Eastern Europe	975	1,013	864	518	430	380	291	261	-2.0	-2.8
Developing Countries										
Asia										
China	2,646	2,241	1,445	693	555	506	400	363	-4.2	-2.7
India	471	538	571	480	425	386	313	285	+0.1	-2.1
South Korea	255	282	215	217	185	169	147	137	-0.5	-1.9
Middle East	364	410	608	610	545	520	463	442	+1.7	-1.3
Africa	352	380	442	373	341	303	268	254	+0.2	-1.6
Central and South America	188	168	169	175	173	161	145	137	-0.2	-1.0
Total World	**302**	**276**	**241**	**202**	**190**	**180**	**161**	**154**	**-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 (2003).

quadrillion Btu, the transitional EE/FSU countries 82 quadrillion Btu, and the developing world 270 quadrillion Btu. In the high economic growth case, total world energy use in 2025 is projected to be 763 quadrillion Btu, 123 quadrillion Btu (or 62 million barrels of oil equivalent) higher than in the reference case (Figure 21). Under the assumptions of the low economic growth case, worldwide energy consumption in 2025 would be 98 quadrillion Btu (or 49 million barrels of oil equivalent) lower than in the reference case, at 542 quadrillion Btu. Thus, there is a substantial range of 221 quadrillion Btu, or about one-third 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 8.6 billion metric tons carbon equivalent in the low economic growth case (1.8 billion metric tons less than the reference case projection of 10.4 billion metric tons carbon equivalent) and 12.4 billion metric tons carbon equivalent in the high economic growth case (2.0 billion metric tons higher than the reference case projection).

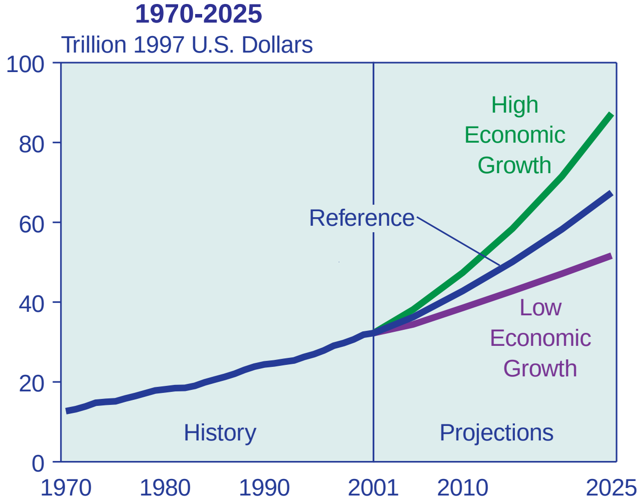
Trends in Energy Intensity

Another major source of uncertainty surrounding a long-term forecast 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 FSU 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 is expected to be more than double that in the developing world and five times that in the industrialized world in 2025 (Figure 22).

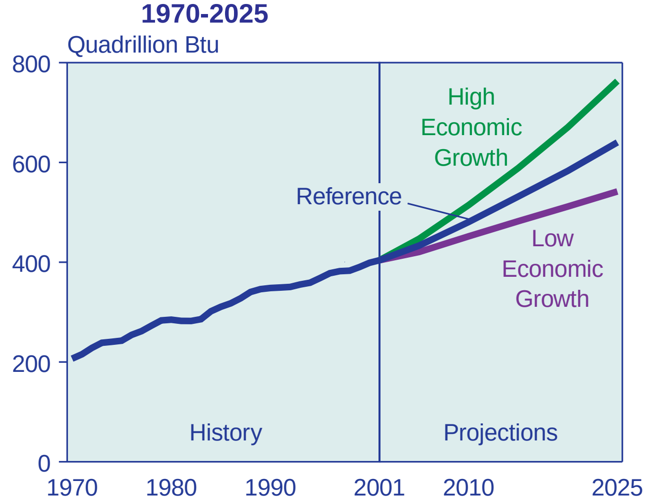
The stage of economic development and the standard of living of individuals in a given region strongly influence the link between economic growth and energy demand. Advanced economies with high living standards have a relatively high level of energy use per capita, but they also tend to be economies 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

Figure 20. 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 2002); and EIA, System for the Analysis of Global Energy Markets (2003).

Figure 21. World Energy Consumption in Three Economic Growth Cases, 1970-2025



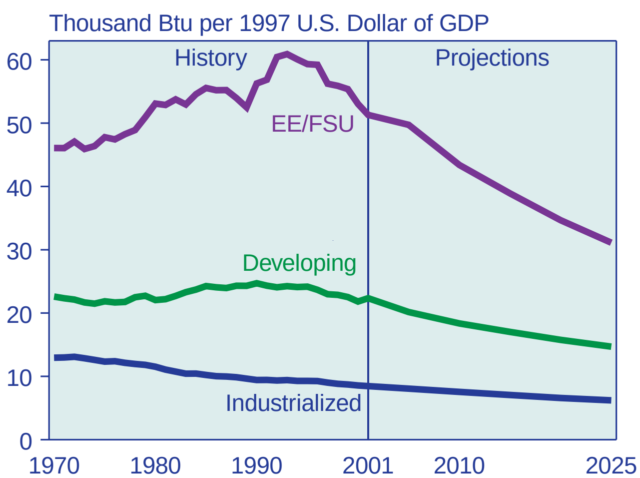
Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2003).

the equipment it replaces, resulting in a weaker link between income and energy demand.

Changing growth patterns of energy intensity could have dramatic impacts on energy consumption in the projection period, particularly among the developing countries. For instance, if energy intensities in each of the developing countries are assumed to improve (decline) annually by a percentage equal to the single greatest annual improvement recorded between 1990 and 2000, energy intensity in the developing world as a whole would fall by 74 percent between 2001 and 2025. Historically, the average of the largest single-year improvements in energy intensity for each of the developing nations has been 5 percent, and the single-year improvements for individual developing countries have ranged from 9 percent (China) to 1 percent (Brazil). If energy intensity in each of the developing countries improved annually over the forecast period at the highest historical rate of improvement recorded for each country in a single year, their combined energy consumption in 2025 would be 105 quadrillion Btu, as compared with the reference case projection of 270 quadrillion Btu.

If, on the other hand, energy intensity in each of the developing countries changed annually at the lowest historical rate of improvement (or the highest rate of worsening) recorded for a single year from 1990 to 2000, energy intensity in the developing world as a whole would increase (worsen) by 169 percent between 2001 and 2025. Historically, the average of the largest single-year increases in energy intensity for each of the developing nations (including the smallest historical decreases in countries where energy intensity has improved every year) has been 4 percent, ranging from an increase of 10 percent (South Korea) to a decrease of 4 percent (China). If energy intensity in each of the developing countries worsened (increased) annually over the forecast period at the highest historical rate recorded for each country in a single year (or improved by the lowest rate recorded for each country where energy intensity has improved every year), their combined energy consumption in 2025 would be 1,078 quadrillion Btu—68 percent higher than the reference case projection.

Figure 22. 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 (2003).

Forecast Comparisons

Three organizations provide forecasts comparable to those in *IEO2003*. The International Energy Agency (IEA) provides "business as usual" projections to the year 2030 in its *World Energy Outlook 2002*. Petroleum Economics, Ltd. (PEL) and Petroleum Industry Research Associates (PIRA) publish world energy forecasts to the year 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.

Regional breakouts among the forecasting groups vary, complicating the comparisons. For example, *IEO2003* 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 *IEO2003* 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 *IEO2003* forecast comprises Japan, Australia, and New Zealand. *IEO2003* 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 *IEO2003*. 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 4). The growth rates for energy consumption among the reference case forecasts for the 2000-2010 time period are similar, ranging between 1.9 and 2.1 percent per year. All the forecasts for total energy consumption fall well within the range of variation defined by the

IEO2003 low and high economic growth cases; in fact, all are within a range of 0.2 percentage points around the *IEO2003* reference case.

The regions for which the largest variations are seen among the forecasts are the Middle East and Africa, with more moderate differences in the projections for Latin America, developing Asia, and the EE/FSU. For both the Middle East and Africa the projected average annual growth rates vary by 1.4 percentage points among the reference case forecasts. For the Middle East, *IEO2003* projects the lowest growth in energy demand in the region at 2.3 percent per year between 2000 and 2010. PEL projects the highest average growth for the Middle East in the 2000-2010 period, at 3.7 percent per year. The PEL and PIRA projections exceed the upper range defined by the *IEO2003* high economic growth case, demonstrating the great uncertainties among the forecasts about the political and economic future of this region in the next decade. For Africa, *IEO2003* also projects the slowest growth in energy use between 2000 and 2010 at 1.9 percent per year, and IEA projects the highest growth rate at 3.3 percent per year. Both the IEA and PEL projections are higher than the *IEO2003* high economic growth case estimate of 2.6 percent per year.

For Latin America, the projected growth rates for the 2000 to 2010 time period vary by 0.9 percentage points among the forecasts, ranging from 2.1 percent per year (PIRA) to 3.0 percent per year (IEA). Only the IEA forecast exceeds the *IEO2003* high economic growth case estimate of 2.6 percent. Projections for the EE/FSU differ by a range of 0.8 percentage points, varying from 1.7-percent annual growth in energy demand between 2000 and 2010 (PEL) to 2.5 percent per year (PIRA). The *IEO2003* reference case projects that energy use in the EE/FSU will increase by 2.3 percent per year over the period.

IEO2003, PIRA, and PEL provide forecasts for energy use in 2015, the end of the PEL and PIRA forecast horizons (Table 5), and their projections for worldwide growth in energy consumption between 2000 and 2015 are similar, ranging from 1.9 percent per year (PEL) to 2.2 percent per year (PIRA), with *IEO2003* expecting average annual growth of 2.0 percent. Regionally, however, there are some differences in the expectations for growth in energy demand, particularly in the industrialized world. Both PIRA and PEL are much more pessimistic about economic expansion in industrialized Asia. PEL expects Japan, Australia, and New Zealand to experience almost no growth in energy use over the 2000-2015 period (0.2 percent per year), whereas *IEO2003* projects 1.2-percent annual growth. The PEL forecast falls well below the lower bound of 0.6 percent per year defined by the *IEO2003* low economic growth case.

Table 4. Comparison of Energy Consumption Growth Rates by Region, 2000-2010
(Average Annual Percent Growth)

Region	*IEO2003*			*IEO2002*	IEA	PIRA	PEL
	Low Growth	Reference	High Growth				
Industrialized Countries	**0.8**	**1.1**	**1.6**	**1.0**	**1.1**	**1.0**	**1.0**
United States and Canada	1.1	1.3	1.7	1.2	1.1	1.0	1.2
Western Europe	0.2	0.8	1.3	0.9	1.1	1.1	1.0
Pacific	0.6	1.2	1.8	0.9	1.2	0.7[a]	0.5
EE/FSU	**1.9**	**2.4**	**3.9**	**1.7**	**1.8**	**2.5**	**1.7**
Former Soviet Union	2.2	2.6	4.2	1.7	—	—	1.8
Eastern Europe	0.9	1.5	3.1	1.7	—	—	1.2
Developing Countries	**1.7**	**2.7**	**3.4**	**2.9**	**3.2**	**3.9**	**3.4**
Asia	1.9	3.2	3.9	4.3	3.4	3.9	3.7
China	2.1	3.9	4.6	5.3	3.2	4.4	4.0
Other Asia[b]	1.7	2.5	3.3	3.5	3.6	3.5	3.5
Middle East	1.4	2.1	3.0	3.0	2.8	3.3	3.7
Africa	1.2	1.9	2.6	2.5	3.3	2.6	2.7
Latin America	1.7	2.2	2.6	2.7	3.0	2.1	2.4
Total World	**1.3**	**1.9**	**2.6**	**2.2**	**1.9**	**2.1**	**2.0**

[a]Japan only.

[b]Other Asia includes India and South Korea.

Sources: ***IEO2003*:** Energy Information Administration (EIA), System for the Analysis of Global Energy Markets (2003). ***IEO2002*:** EIA, *International Energy Outlook 2002*, DOE/EIA-0484(2002) (Washington, DC, March 2002), Table A1, p. 179. **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 2002), Tables 11-4, 11-6, and 11-7. **PEL:** Petroleum Economics, Ltd., *Oil and Energy Outlook to 2015* (London, United Kingdom, June 2002), Table 2i.

IEO2003 and IEA provide energy consumption projections for 2020 (Table 6). IEA projects slightly slower growth in world energy demand over the 2000-2020 period. In particular, expectations for demand growth in the United States and Canada are lower in the IEA forecast than in the *IEO2003* reference case. *IEO2003* also expects a higher growth rate in consumption for the EE/FSU over this time period, at 1.9 percent per year compared with the IEA forecast of 1.5 percent per year. On the other hand, IEA foresees much stronger growth

Table 5. Comparison of Energy Consumption Growth Rates by Region, 2000-2015
(Average Annual Percent Growth)

Region	*IEO2003*			*IEO2002*	PIRA	PEL
	Low Growth	Reference	High Growth			
Industrialized Countries	**0.8**	**1.1**	**1.6**	**1.2**	**1.0**	**0.5**
United States and Canada	1.1	1.4	1.7	1.5	1.1	1.1
Western Europe	0.2	0.7	1.3	0.9	0.9	0.8
Pacific	0.6	1.2	1.8	0.9	0.7	0.2
EE/FSU	**1.6**	**2.1**	**3.5**	**1.8**	**2.5**	**1.7**
Former Soviet Union	1.8	2.3	3.6	1.8	—	1.8
Eastern Europe	1.0	1.6	3.4	1.7	—	1.2
Developing Countries	**1.8**	**2.9**	**3.6**	**3.8**	**3.4**	**3.2**
Asia	2.0	3.3	4.0	4.2	3.8	3.5
China	2.1	3.9	4.5	5.0	4.2	3.5
Other Asia[a]	1.9	2.7	3.6	3.4	3.6	3.4
Middle East	1.3	2.3	3.2	3.0	3.3	3.3
Africa	1.3	2.0	2.7	2.6	2.5	2.6
Latin America	1.9	2.6	3.1	3.8	2.3	2.7
Total World	**1.3**	**1.9**	**2.6**	**2.3**	**2.2**	**1.9**

[a]Other Asia includes India and South Korea.

Sources: ***IEO2003*:** Energy Information Administration (EIA), System for the Analysis of Global Energy Markets (2003). ***IEO2002*:** EIA, *International Energy Outlook 2002*, DOE/EIA-0484(2002) (Washington, DC, March 2002), Table A1, p. 179. **PIRA:** PIRA Energy Group, *Retainer Client Seminar* (New York, NY, October 2002), Tables II-4, II-6, and II-7. **PEL:** Petroleum Economics, Ltd., *Oil and Energy Outlook to 2015* (London, United Kingdom, June 2002), Table 2i.

Table 6. Comparison of Energy Consumption Growth Rates by Region, 2000-2020
(Average Annual Percent Growth)

Region	*IEO2003*			*IEO2002*	IEA
	Low Growth	Reference	High Growth		
Industrialized Countries	**0.7**	**1.1**	**1.6**	**1.2**	**1.0**
United States and Canada	1.1	1.4	1.7	1.4	1.1
Western Europe	0.2	0.7	1.4	0.9	0.9
Pacific	0.6	1.1	1.7	0.9	1.0
EE/FSU	**1.2**	**1.9**	**3.3**	**1.7**	**1.5**
Former Soviet Union	1.4	2.0	3.2	1.7	—
Eastern Europe	0.8	1.8	3.6	1.7	—
Developing Countries	**1.9**	**2.9**	**3.7**	**3.7**	**3.1**
Asia	2.0	3.2	4.0	4.0	3.1
China	2.1	3.8	4.5	4.8	3.0
Other Asia[a]	1.9	2.7	3.6	3.2	3.3
Middle East	1.5	2.3	3.3	2.9	2.5
Africa	1.4	2.1	2.8	2.6	3.4
Latin America	2.1	2.7	3.3	3.8	2.9
Total World	**1.2**	**1.9**	**2.6**	**2.2**	**1.8**

[a]Other Asia includes India and South Korea.

Sources: ***IEO2003*:** Energy Information Administration (EIA), System for the Analysis of Global Energy Markets (2003). ***IEO2002*:** EIA, *International Energy Outlook 2002*, DOE/EIA-0484(2002) (Washington, DC, March 2002), Table A1, p. 179. **IEA:** International Energy Agency, *World Energy Outlook 2002* (Paris, France, September 2002), pp. 410-497.

in Africa's energy consumption, projecting 3.4-percent average annual growth between 2000 and 2020, well in excess of the *IEO2003* high economic growth case projection of 2.8 percent per year.

Finally, the projections vary not only with respect to levels of total energy demand but also with respect to the composition of primary energy inputs. All the forecasts provide energy consumption projections by fuel in 2010 (Table 7). In terms of oil consumption, all the forecasts expect similar growth worldwide between 2000 and 2010. Oil demand is projected to increase by between 1.5 percent per year (*IEO2003*) and 1.8 percent per year (PIRA). All the forecasts expect natural gas use to grow more rapidly than other fuels between 2000 and 2010 and nuclear power to grow more slowly than any other fuel. The projections for growth in coal use vary among the forecasts, from 1.4 percent per year (PEL and IEA) to 2.2 percent per year (PIRA), with *IEO2003* projecting 1.6-percent average annual growth from 2000 to 2010. Although IEA projects the slowest growth among the forecasts for coal, it projects the highest growth rate for renewable energy sources (2.8 percent per year), making up for any shortfall in projected coal use.

PEL, PIRA, and *IEO2003* provide world energy consumption projections by fuel for 2015 (Table 8). The three forecasts offer similar views of the future use of natural gas, which is the fastest growing primary fuel type for each forecast between 2000 and 2015, ranging from 2.8 percent per year (*IEO2003*) to 3.3 percent per year (PIRA). In all the forecasts, the slowest growth is projected for nuclear power. The *IEO2003* reference case projection for growth in nuclear power consumption, at 1.1 percent per year, is higher than the two other forecasts (PEL, 0.3 percent per year and PIRA, 0.4 percent per year).

IEO2003 and IEA are the only forecasts that provide projections for 2020 (Table 9). The IEA forecast shows slower projected growth than the *IEO2003* forecast for every fuel type except renewable energy; however, the overall trends are similar in the two forecasts, with growth in natural gas use expected to exceed that for oil and coal and nuclear power expected to be the slowest growing energy source over the 2000-2020 time period.

Table 7. Comparison of World Energy Consumption Growth Rates by Fuel, 2000-2010
(Average Annual Percent Growth)

Fuel	*IEO2003*			*IEO2002*	IEA	PIRA	PEL
	Low Growth	Reference	High Growth				
Oil	0.8	1.5	2.3	2.2	1.7	1.8	1.6
Natural Gas	2.1	2.5	3.4	3.0	3.0	3.2	3.3
Coal	0.7	1.7	2.4	1.9	1.4	2.2	1.4
Nuclear	1.3	1.3	1.5	0.7	1.1	0.5	0.9
Renewable/Other	2.2	2.4	2.6	2.1	2.8	1.5	2.2
Total	**1.3**	**1.9**	**2.6**	**2.2**	**1.9**	**2.1**	**2.0**

Sources: ***IEO2003*:** Energy Information Administration (EIA), System for the Analysis of Global Energy Markets (2003). ***IEO2002*:** EIA, *International Energy Outlook 2002*, DOE/EIA-0484(2002) (Washington, DC, March 2002), Table A1, p. 179. **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 2002), Table 11-8. **PEL:** Petroleum Economics, Ltd., *Oil and Energy Outlook to 2015* (London, United Kingdom, June 2002), Table 2i.

Table 8. Comparison of World Energy Consumption Growth Rates by Fuel, 2000-2015
(Average Annual Percent Growth)

Fuel	*IEO2003*			*IEO2002*	PIRA	PEL
	Low Growth	Reference	High Growth			
Oil	0.9	1.7	2.5	2.2	1.8	1.6
Natural Gas	2.2	2.8	3.5	3.1	3.3	3.2
Coal	0.7	1.6	2.2	1.8	2.2	1.1
Nuclear	1.0	1.1	1.6	0.5	0.4	0.3
Renewable/Other	1.9	2.1	2.5	2.2	1.7	2.3
Total	**1.3**	**1.9**	**2.6**	**2.2**	**2.2**	**1.9**

Sources: ***IEO2003*:** Energy Information Administration (EIA), System for the Analysis of Global Energy Markets (2003). ***IEO2002*:** EIA, *International Energy Outlook 2002*, DOE/EIA-0484(2002) (Washington, DC, March 2002), Table A1, p. 179. **PIRA:** PIRA Energy Group, *Retainer Client Seminar* (New York, NY, October 2002), Table 11-8. **PEL:** Petroleum Economics, Ltd., *Oil and Energy Outlook to 2015* (London, United Kingdom, June 2002), Table 2i.

Table 9. Comparison of World Energy Consumption Growth Rates by Fuel, 2000-2020
(Average Annual Percent Growth)

Fuel	*IEO2003* Low Growth	*IEO2003* Reference	*IEO2003* High Growth	*IEO2002*	IEA
Oil	1.0	1.7	2.6	2.2	1.7
Natural Gas	2.3	2.8	3.5	3.1	2.7
Coal	0.6	1.6	2.2	1.8	1.4
Nuclear	0.7	0.8	1.3	0.4	0.3
Renewable/Other	1.6	1.9	2.4	2.1	2.7
Total	**1.3**	**1.9**	**2.6**	**2.2**	**1.8**

Sources: ***IEO2003*:** Energy Information Administration (EIA), System for the Analysis of Global Energy Markets (2003). ***IEO2002*:** EIA, *International Energy Outlook 2002*, DOE/EIA-0484(2002) (Washington, DC, March 2002), Table A1, p. 179. **IEA:** International Energy Agency, *World Energy Outlook 2002* (Paris, France, September 2002), p. 410.

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, we present a comparison of *IEO* forecasts produced for the years 1990, 1995, and 2000. 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*, mid-term 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.

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), 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 10). 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 and this year the *IEO2003* forecast extends to 2025 for the first time.

Table 10. Years Included in *IEO* Projections by Edition, 1985-2003

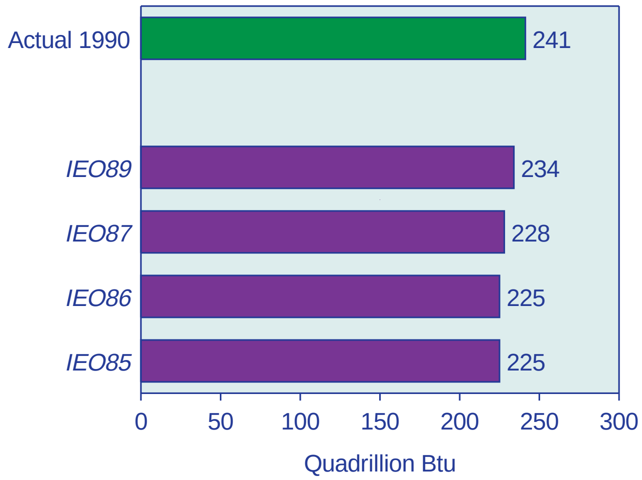
Edition	1990	1995	2000	2005	2010	2015	2020	2025
IEO85	x	x						
IEO86	x	x	x					
IEO87	x	x	x					
IEO89	x	x	x					
IEO90		x	x		x			
IEO91		x	x		x			
IEO92		x	x		x			
IEO93		x	x		x			
IEO94			x	x	x			
IEO95			x	x	x			
IEO96		x	x	x	x	x		
IEO97			x	x	x	x		
IEO98			x	x	x	x	x	
IEO99			x	x	x	x	x	
IEO2000				x	x	x	x	
IEO2001				x	x	x	x	
IEO2002				x	x	x	x	
IEO2003				x	x	x	x	x

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

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 23).

Figure 23. Comparison of *IEO* Forecasts with 1990 Energy Consumption in Market Economies



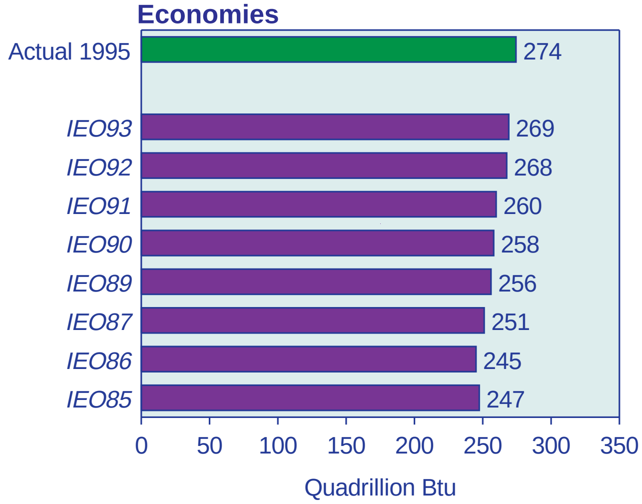
Sources: Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/, and *International Energy Outlook*, DOE/EIA-0484 (Washington, DC, various years).

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 24). 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 25). The consumption estimates for the market economies increased in each edition, from 265 quadrillion Btu in *IEO86* to 292 quadrillion Btu in *IEO93*. Even 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).

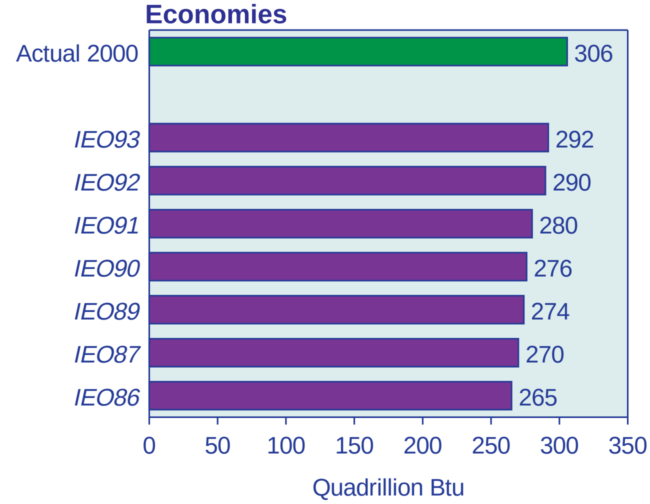
As noted above, in the 1994 edition of the *IEO*, the regional aggregation "market economies" was dropped altogether and replaced with delineation of member countries of the OECD, Eurasia, and Rest of World (ROW). As a result of that reorganization, it is not

Figure 24. 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 25. 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).

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."

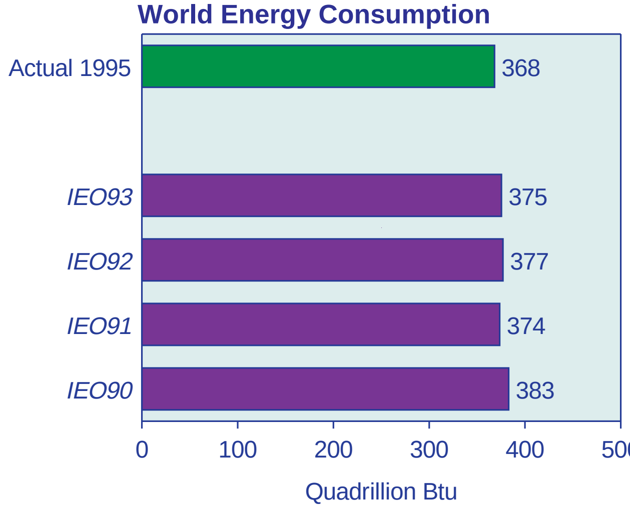
Comparisons of Forecasts for Year 1995

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 26). 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 27) 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 28). 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.

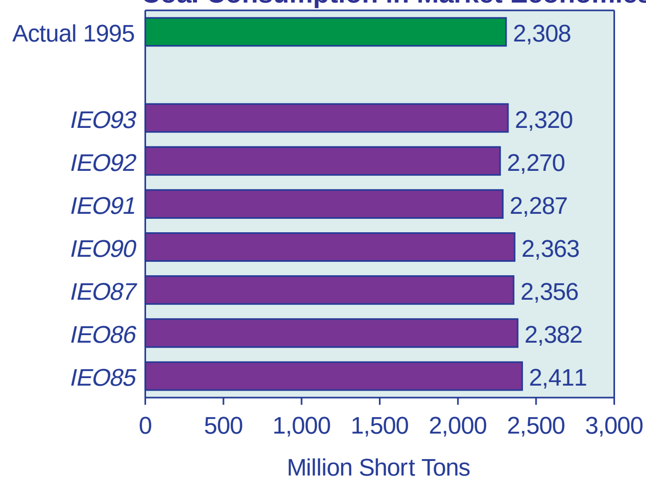
The 1995 forecasts for world coal consumption that appeared in the *IEOs* printed between 1990 and 1993 were consistently high, between 3 and 19 percent higher than actual coal use (Figure 29), largely because of overestimates for the FSU and Eastern Europe—regions that experienced substantial declines in coal consumption

Figure 26. Comparison of *IEO* Forecasts with 1995 World Energy Consumption



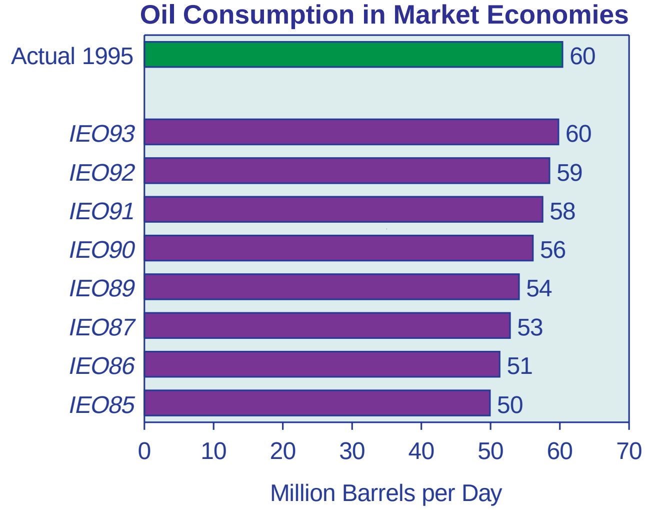
Sources: Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/, and *International Energy Outlook*, DOE/EIA-0484 (Washington, DC, various years).

Figure 27. 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 28. Comparison of *IEO* Forecasts with 1995 Oil Consumption in Market Economies

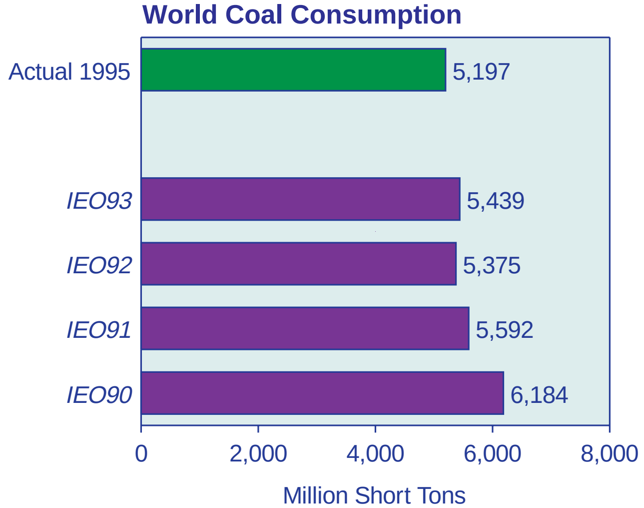


Sources: Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/, and *International Energy Outlook*, DOE/EIA-0484 (Washington, DC, various years).

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 30). 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 30- to 54-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 31). 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.

Figure 29. Comparison of *IEO* Forecasts with 1995 World Coal Consumption

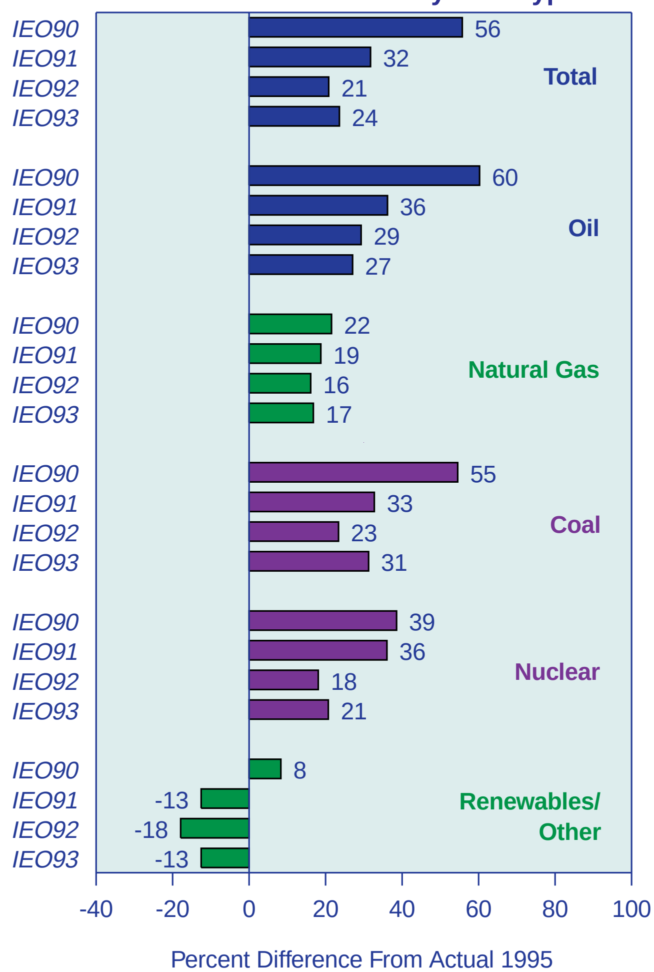


Sources: Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/, and *International Energy Outlook*, DOE/EIA-0484 (Washington, DC, various years).

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 32). *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 33) 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

Figure 30. Comparison of *IEO* Forecasts with 1995 Energy Consumption in the Former Soviet Union by Fuel Type



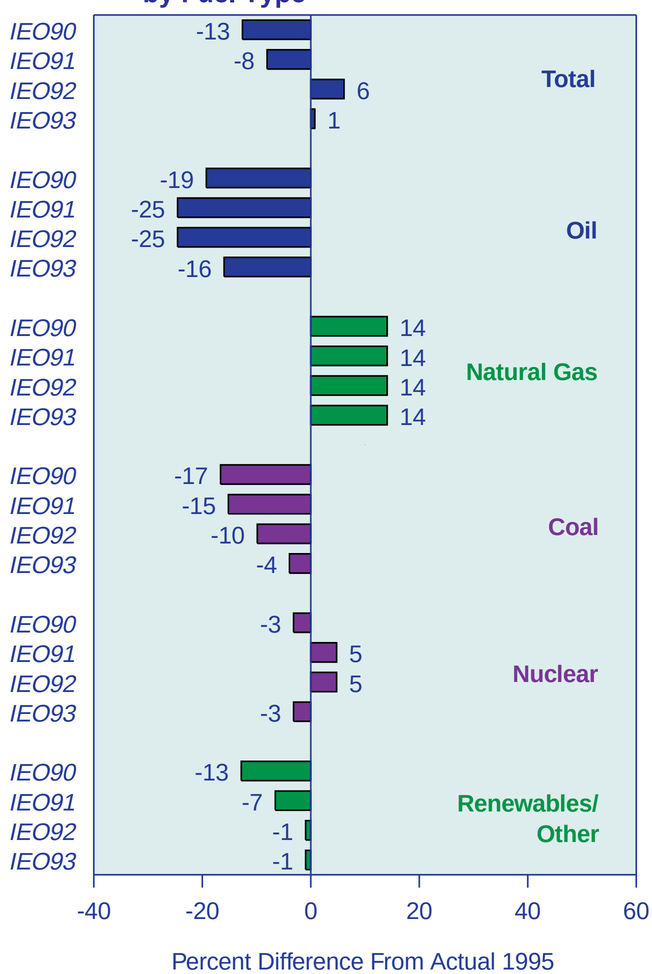
Sources: Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/, and *International Energy Outlook*, DOE/EIA-0484 (Washington, DC, various years).

energy consumption by 7 quadrillion Btu (13 percent). *IEO97* did not anticipate the August 1998 devaluation of the Russian ruble and 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 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.

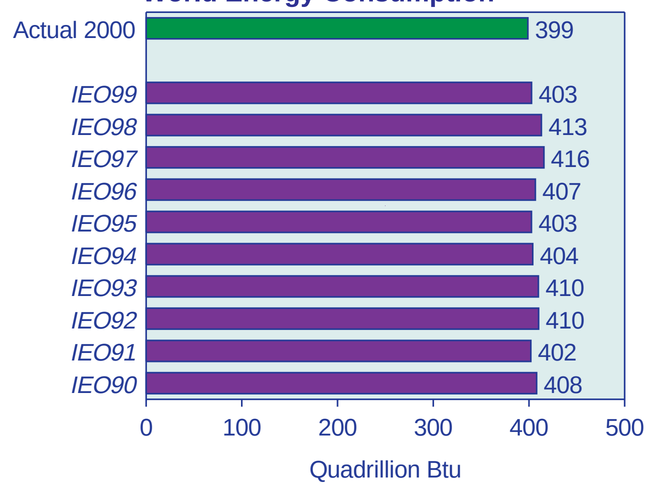
Much of the discrepancy between the *IEO90* projection and actual 2000 coal consumption can be attributed to

Figure 31. Comparison of *IEO* Forecasts with 1995 Energy Consumption in China by Fuel Type



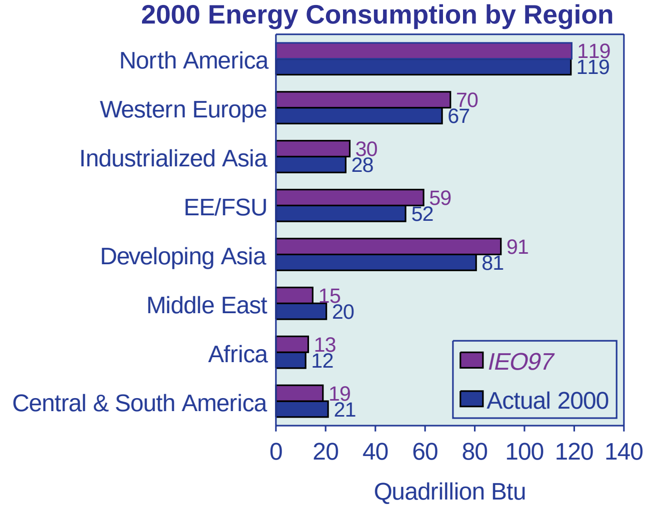
Sources: Energy Information Administration, *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/, and *International Energy Outlook*, DOE/EIA-0484 (Washington, DC, various years).

Figure 32. 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 33. 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).

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 Eastern Europe and the 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.

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World Oil Markets

In the IEO2003 forecast, periodic production adjustments by OPEC members are not expected to have a significant long-term impact on world oil markets. Prices are projected to rise gradually through 2025 as the oil resource base is further developed.

Throughout most of 2002, crude oil prices were solidly within the range preferred by producers in the Organization of Petroleum Exporting Countries (OPEC), $22 to $28 per barrel for the OPEC "basket price" (see Figure 14 on page 9). OPEC producers have been demonstrating disciplined adherence to announced cutbacks in production. Early in 2003, a dramatic upward turn in crude oil prices was brought about by a combination of two factors. First, a general strike against the Chavez regime resulted in a sudden drop in Venezuela's oil exports. Although other OPEC producers agreed to increase production to make up for the lost Venezuelan output, the obvious strain on worldwide spare capacity kept prices high. Second, price volatility was exacerbated by fears of war in Iraq.

Although the labor turmoil in Venezuela appears to be ending, world oil prices are expected to remain near $30 per barrel (for West Texas Intermediate crude oil, in nominal dollars) throughout most of 2003, mainly because of the war in Iraq and its aftermath. Due to differences in crude oil qualities, such a price is consistent with the lower portion of the OPEC price band. A softening of oil prices is anticipated in 2004 but is not expected to endure if OPEC maintains its recent successes in market management through production cutbacks. OPEC producers might find it more challenging to firm up oil prices over the next few years, however, given the expected increase in non-OPEC supply. They not only will have to demonstrate discipline within their own ranks but also may try to convince selected non-OPEC producers of the merits of production cutbacks. It remains to be seen whether such a coalition of OPEC and non-OPEC producers can demonstrate the restraint necessary to influence production objectives. Despite evidence that OPEC has achieved some of its price goals in recent years, production cutback strategies have historically had mixed success.

World oil consumption rose in 2002 by about 300 thousand barrels per day, scattered evenly among the industrialized nations (mainly North America) and developing nations (mainly Asia). Although the developing Asian economies are no longer in recession, their current growth is modest by comparison with their rapid economic expansion during the early and mid-1990s. Latin America's oil demand has also shown only modest growth since 1999. In the former Soviet Union (FSU), where oil demand grew in 2000 for the first time in more than a decade, there were slight increases in demand in both 2001 and 2002. In 2003, world oil demand is expected to grow by about 1.2 million barrels per day [***1***].

OPEC members have agreed to production increases that will add whatever volumes are necessary to replace the lost Venezuelan and Iraqi output. It is anticipated that the increases will somewhat temper any price escalation, but that uncertainty about post-war Iraq will keep the world oil price (U.S. refiner acquisition cost for imports) higher than market fundamentals might dictate.

OPEC's recent successes have been the result of tight market conditions and disciplined participation by OPEC members. Currently, spare production capacity worldwide is low, 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 members of OPEC have announced plans to expand production capacity over the next several years. In an oil market environment with substantial spare production capacity, it will 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 700 thousand barrels per day in 2001 and by an additional 1 million barrels per day in 2002, and it is expected to increase by an impressive 1.4 million barrels per day in 2003. Almost one-half of the total increase in non-OPEC production over the next 2 years is expected to come from the FSU. The remainder of the expected increase is evenly divided between producers in industrialized nations and those in developing economies.

Incorporating the recent price turbulence into the construction of an intermediate- and 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 market? Will sustained and robust economic growth in developing countries return in the aftermath of the severe setback to the Asian economies in 1997-1999? Will new technology 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 promise to go even higher in 2003, those developments are not indicative of the trend in the *International Energy Outlook 2003* (*IEO2003*) reference case. In the short term, oil prices are expected to reflect the market uneasiness brought about by the war in Iraq. From anticipated high levels throughout 2003, oil prices are projected to decline significantly to $23.27 in 2005 before rising by about 0.7 percent per year to $26.57 in 2025 (all prices in 2001 dollars unless otherwise noted). When the economic recovery in Asia is complete, demand growth in developing countries throughout the world is expected to be sustained at robust levels. Worldwide oil demand is projected to reach almost 119 million barrels per day by 2025, requiring an increment to world production capability of more than 42 million barrels per day over current capacity. OPEC producers are expected to be the major suppliers of increased production, but non-OPEC supply is expected to remain competitive, with major increments to supply coming from offshore resources, especially in the Caspian Basin, Russia, 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 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 over long periods. 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 proved reserves (i.e., economically viable) when prices rise, and non-conventional sources of oil that become proved 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 *IEO2003* low and high world oil price cases suggest that the projected trends in growth for oil production are sustainable without severe oil price escalation. There are some oil market analysts, however, who find this viewpoint to be overly optimistic, based on what they consider to be a significant overestimation of both proved reserves and ultimately recoverable resources.

Highlights of the *IEO2003* projections for the world oil market are as follows:

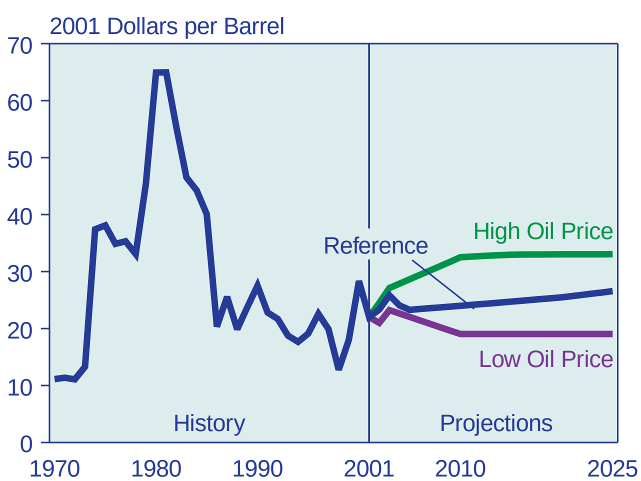
- The reference case oil price projection shows a dramatic increase from 2002 to 2003 as a result of the Venezuelan labor strike and the war in Iraq, a brief decline through 2005, and a modest 0.7-percent average annual increase out to 2025.
- Deepwater exploration and development initiatives are generally 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, however, 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 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 *IEO2003* reference case projections are significant. The war 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 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.

World Oil Prices

The near-term price trajectory in the *IEO2003* reference case is considerably different from that in *IEO2002*. Last year's reference case price path did not reflect the upward price pressure in 2003 brought about by the situations in Iraq and Venezuela. In the longer term, oil prices in both the *IEO2003* and *IEO2002* reference cases are projected to rise gradually over the last two decades of the forecast period; however, *IEO2003* projects average annual increases of 0.7 percent, as compared with 0.5 percent in the *IEO2002* forecast. The more robust price growth in the *IEO2003* reference case reflects the recognition that OPEC has been able to adhere to a production cutback strategy for the purpose of firming up prices. Three possible long-term price paths are shown in Figure 34. In the reference case, projected prices in 2001 dollars reach $26.57 in 2025. (In nominal dollars, the reference case price is expected to exceed $48 in 2025.) In the low price case, prices are projected to reach $19.04 by 2009 and to remain at about that level out to 2025. In the high price case, prices are projected to reach $32.95 by 2015 and to remain at about that level out to 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 level.

In all the *IEO2003* oil price cases, oil demand is expected to rise significantly over the projection period. The projected rise in oil consumption ranges from a low of 36 million barrels per day in the high price case to a high of 48 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. Rather more important are the political, economic, and environmental circumstances that could shape developments in oil supply and demand.

Figure 34. 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:** 2002-2003—EIA, *Short-Term Energy Outlook*, on-line version (April 2003), web site www.eia.doe.gov/emeu/steo/pub/contents.html. 2003-2025—EIA, *Annual Energy Outlook 2003*, DOE/EIA-0383 (2003) (Washington, DC, January 2003).

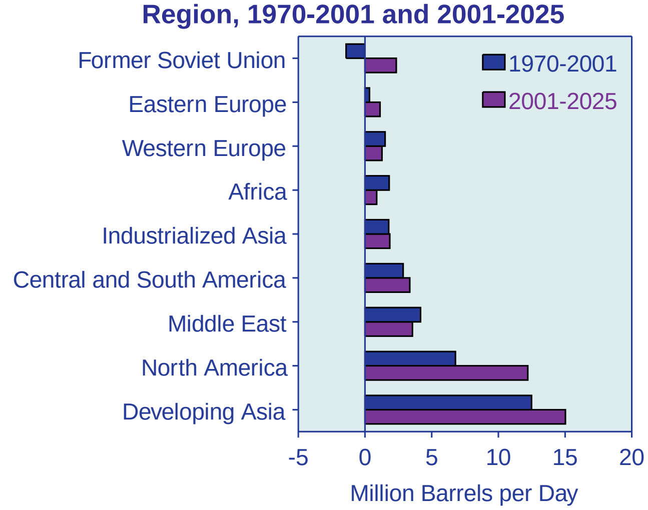
World Oil Demand

World oil demand is projected to grow to 119 million barrels per day by 2025 in the *IEO2003* reference case. Over the forecast period, oil remains the fuel of choice in the transportation sector worldwide, and almost three-quarters of the projected increase in oil demand from 2001 to 2025 comes from the transportation sector, particularly in developing countries that currently have a lower proportion of transportation fuels in their energy mix.

During the outlook period, global economic growth, the main driver of oil demand growth, is expected to average 3.1 percent per year. The highest rates of economic growth from 2001 to 2025 are expected in developing Asia, led by China and India at 6.2 percent and 5.2 percent, respectively. As a result, the developing countries' share of world oil demand is projected to increase from 36 percent in 2001 to 43 percent in 2025, with a corresponding drop in the industrialized countries' share from 57 percent in 2001 to 50 percent in 2025. In absolute terms (Figure 35), the largest regional increases in oil demand are projected for North America (12.2 million barrels per day) and developing Asia (15.0 million barrels per day).

The smallest increase is projected for Western Europe, where transportation and other end-use infrastructures are more mature and population growth is relatively slow. Even so, the large amount of oil used for transportation in Western Europe ensures that oil will continue to be the dominant fuel used in Europe, accounting for

Figure 35. Increments in Oil Consumption by Region, 1970-2001 and 2001-2025



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/. **2025:** EIA, System for the Analysis of Global Energy Markets (2003).

more than 39 percent of primary energy use in the reference case forecast.

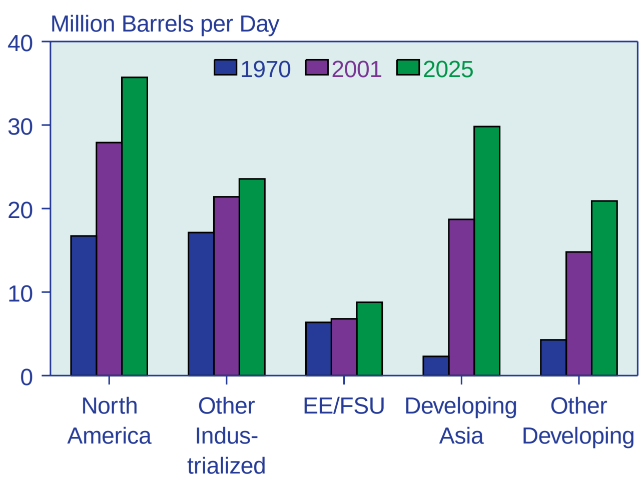
North America

North America is the largest consumer of oil in the world, accounting for more than one-fourth of total demand in 2001 (Figure 36). Oil consumption in the transportation sector currently represents 66 percent of North America's total oil demand. That share is expected to continue to increase as oil use declines in other end-use sectors (for example, natural gas is expected to displace most oil use for electricity generation).

Among the different refined petroleum products consumed, the strongest growth in demand in North American oil markets is projected for gasoline. In contrast, jet fuel consumption, estimated at 1.9 million barrels per day in 2001, has been declining in the wake of airline industry troubles since 2000 and the September 11, 2001, terrorist attacks in New York and Washington, DC, using civilian airplanes. When the prices of jet fuel reached a peak at the end of 2000, many carriers added fuel charges to their ticket and cargo prices. Jet fuel prices eased in 2001, weakened by the U.S. economic slowdown, but new security measures are now becoming an important cost component for airlines that may further depress demand growth.

Oil demand in the United States is projected to grow by 1.7 percent per year to 29.2 million barrels per day in 2025 from 19.6 million barrels per day in 2001. Most of the growth is projected for the transportation sector, with cars and light truck fleets—including sport utility vehicles (SUVs)—being the largest consuming segment of the sector. The airlines industry is expected to be struggling for the next 5 years before positive growth in jet fuel demand resumes for the rest of the outlook period.

Figure 36. World Oil Consumption by Region, 1970, 2001, 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/. **2025:** EIA, System for the Analysis of Global Energy Markets (2003).

In 2002, U.S. automakers began offering generous financing deals for SUVs and other passenger vehicles to bolster demand levels. SUVs now form a distinctive part of the U.S. landscape. There were a reported 66 SUV/sport wagon models on sale in the United States during 2001, and some estimates expect that number to rise to more than 80 models by 2005. Some other estimates suggest that the SUV share of the U.S. market could rise by 40 percent over the next 5 years, with the market share for crossover vehicles—which share some characteristics of the station wagon segment—possibly rising by as much as 58 percent [***2***].

Despite their popularity with the public, SUVs remain a controversial choice of vehicle because of their relatively low fuel economies. Ironically, some observers point to the original introduction of corporate average fuel economy (CAFE) standards during the 1970s as being instrumental in pushing automakers toward building SUVs. With those standards allowing average fuel economy of 27.5 miles per gallon for cars and 20.7 miles per gallon for light truck fleets, automakers claim that they were unable to build larger sedans for bigger families and, instead, sought refuge by building up their product mixes towards light trucks. The comparatively low prices of both vehicles and vehicle fuels in the United States as compared with much of the rest of the world have allowed SUVs to remain sufficiently economical for U.S. consumers to buy and run—far more so than in Western Europe, for example.

As in the United States, the transportation sector is the major source of oil demand growth in the Canadian market; however, the Canadian federal government ratified the Kyoto Protocol in December 2002 and is moving to introduce regulations that could slow the trend. In the *IEO2003* reference case, oil demand in Canada is expected to grow by 1 percent per year on average, to 2.4 million barrels per day in 2025.

In Mexico, long-term economic growth is expected to remain strong at 5.2 percent per year over the forecast period; however, many of the reforms needed for such growth to materialize probably will not happen in the short to mid-term [***3***]. Over the long term, Mexico's closeness to the U.S. economy and its participation in the North America Free Trade Agreement (NAFTA) are two major factors that should enable the country to continue on its path toward economic modernization. Oil demand in Mexico is projected to grow by 3.2 percent per year, from 1.9 million barrels per day in 2001 to 4.1 million barrels per day in 2025.

Western Europe

A decade of mediocre economic growth and the penetration of natural gas have acted to constrain overall oil consumption in Western Europe, except in the transportation sector. Oil demand in Western Europe is projected to grow by only 0.4 by percent per year, from 14 million barrels per day in 2001 to 15.3 million barrel per day in 2025, with little or no increase in the United Kingdom, Germany, France, and Italy.

Demand for diesel fuel in Western Europe has grown by 50 percent since 1990, while gasoline demand has declined marginally. Future growth in diesel demand may be constrained, however, in light of the controversial findings linking possible carcinogenic properties of particulate emissions to the burning of diesel fuel. In addition, the ratification of the Kyoto Protocol by Western European countries through the European Union reflects a general consensus over questions related to climate change, in which the vast majority of the projected growth of carbon dioxide emissions will come from the transportation sector [***4***]. In the *IEO2003* reference case, oil remains the dominant fuel used in Western Europe, but its share of total primary energy consumption shrinks from 42 percent in 2001 to 39 percent in 2025.

Industrialized Asia

In industrialized Asia, oil demand is expected to grow more rapidly in Australia and New Zealand than in Japan. Oil use in Australia and New Zealand is projected to grow by 2.3 percent per year, from 1 million barrels per day in 2001 to 1.7 million barrels per day in 2025, reflecting higher expectations for population growth and economic expansion. In Japan, the projected increase averages only 0.8 percent per year, from 5.4 million barrels per day in 2001 to 6.5 million barrels per day in 2025. In absolute terms, oil consumption in New Zealand is lower than that in Australia or Japan; however, moderate improvements in New Zealand's economic growth outlook are accompanied by a higher projected growth rate for oil demand through 2025 [***5***].

In 2002, Japan's oil demand fell for the third consecutive year. Demand for fuel oil by large industries and electric utilities continued to fall as a result of Japan's prolonged economic recession. Between September and December 2002, there was an unexpected increase (some 130 thousand barrels per day) in demand for fuel oil in Japan's electricity sector as a result of a series of nuclear reactor shutdowns [***6***]. Operation of as many as 17 nuclear reactors (totaling more than 12,300 megawatts of capacity) has been suspended pending safety inspections, after manipulation of inspection data that began in the mid-1980s was uncovered [***7***]. This is expected to be a temporary aberration, and nuclear generation is expected to regain its share of the Japanese electricity market in the near future.

Eastern Europe and the Former Soviet Union

In the *IEO2003* reference case, total oil demand in the FSU and Eastern Europe is projected to reach 7.9 million barrels per day in 2020 (2.2 million barrels per day less than projected in *IEO2002*) and 8.8 million barrels per day in 2025.

The lack of oil resources in Eastern Europe, in contrast to the abundance of coal, has limited the share of oil in the energy mix to an estimated 26 percent in 2001. Oil demand in Eastern Europe—mainly for use in the transportation sector—is projected to grow by 2.5 percent per year, to 2.5 million barrels per day in 2025, rising to about 29 percent of total energy consumption.

Poland, the largest economy in Eastern Europe and a candidate for membership in the European Union in 2004, received the greatest amount of regional investment in the 1990s. Its economy has slowed over the past 2 years, however, leading to high unemployment, rising interest rates, and falling demand for oil. Still, however, Poland arguably offers the greatest potential for future growth in oil demand in the Eastern Bloc in terms of potential market size. The person per car ratio is 4.2 in Poland, which is much higher than in many other countries in Europe (for example, Germany at about 1.7 and the Czech Republic at about 2.8 persons per car) [***8***]. The high ratio in Poland indicates room for expansion in the automotive market and related demand for transportation fuels.

Strong economic growth has continued for the past 5 years in hydrocarbon-oriented economies such as Russia, Kazakhstan, Azerbaijan, and Turkmenistan, supported by high earnings from oil and gas exports and continued foreign investment. In the *IEO2003* reference case, GDP growth in the FSU countries is projected to average 3.8 percent per year from 2001 to 2025, and oil demand is expected to grow by 2 percent per year, from 3.9 million barrels per day in 2001 to 6.2 million barrels per day in 2025.

The transportation sector, particularly trucking, is expected to be the major source of oil demand growth in the FSU region. Also, given the huge geographical expanse of Russia, the largest economy in the region, a continued increase in demand for air travel, and as a result demand for jet fuel, can be expected to continue with rising personal incomes. Apart from the transportation sector, oil demand in the FSU continues to decline in the power generation and industrial sectors, mainly because of improvements in efficiency and substitution of natural gas for fuel oil.

Developing World

In the *IEO2003* reference case, oil demand in the developing world is projected to reach 50.7 million barrels per day by 2025. In developing Asia, India's growth in oil demand has slowed substantially in recent years, and the high growth rate of the 1990s is not expected to be sustained over the next two decades, as India moves further toward less oil-intensive economic activities, such as services and information technology.

Developing Asia has managed to avoid the global slump of 2001 through robust regional economic growth, strong consumer confidence, low interest rates, and progressive liberalization of trade. Demand for road transportation fuels, in particular, is surging ahead to pre-Asia crisis levels of 1998. This trend is projected to continue, led by China and India, the two largest economies in the region. Oil demand in developing Asia is projected to reach 29.8 million barrels per day in 2025.

China

Oil demand has continued to climb in China with increasing motorization and switching away from coal and traditional, noncommercial fuels in the residential and service sectors. Oil demand in China is projected to grow by 3.3 percent per year on average, from 5 million barrels per day in 2001 to 10.9 million barrels per day in 2025. Most of the additional oil will have to be imported.

In 2001, vehicle ownership in China was 13 vehicles per 1,000 persons, as compared with 779 per 1,000 in the United States. China's accession to the World Trade Organization in 2001 is expected to increase competition in the automobile sector, stimulating passenger car sales and demand for transportation fuels. Car prices are expected to fall by around 15 percent as a result of increased competition from imports. China's road system is still failing to keep up with growth in vehicle use, however, and its major cities already face gridlock. In addition to poor road infrastructure, China has a lack of parking facilities. The government carried out massive infrastructure development in 2002, involving 251 highway projects covering 16,104 miles, at a cost of $ 4.1 billion [***9***]. The government plans for all counties in undeveloped western China to have access to a highway by the end of the year.

With strong growth in automobile use throughout the country, the Chinese government has also become increasingly concerned about air quality, particularly in urban areas. In preparation for the Beijing Olympics in 2008, the Chinese government is planning to phase out leaded gasoline and has pledged to replace 1.8 million outdated vehicles [***10***].

India

India's GDP growth rates of 5 to 7 percent, sustained over several years, have been better than anywhere in the world except China. They have been achieved without the massive social dislocation that threatens stability in China and parts of Southeast Asia and were sustained throughout the financial shocks that hit Southeast Asia in 1997 [***11***]. India's GDP growth is projected to average 5.2 percent per year from 2001 to 2025, and oil demand is projected to grow by 4 percent per year, from 2.1 million barrels per day in 2001 to 5.5 million barrels per day in 2025. About 70 percent of the increase in oil demand is projected for the transportation sector. The Indian government plans to spend $12.5 billion upgrading existing roads and constructing two East-West and North-South highways that will span the country by the end of 2003 [***12***]. India's roads sector is believed to be among the fastest growing infrastructure areas in the country. On the other hand, the impact of high oil prices in 2000 and 2001, the drought that weakened oil demand in the agricultural sector, the massive earthquake that struck the prosperous state of Gujarat in January 2001, and the devastating monsoon (the first in a decade) in 2002 have made sustaining the high oil demand growth registered during the 1990s difficult to achieve over the past 2 years.

Diesel fuel has historically been much cheaper than gasoline in India. A substantial rise in gasoline prices in 1976 led to the conversion of almost all commercial vehicles to diesel engines. The continuous increase in gasoline prices and the subsidy provided to diesel progressively increased demand for diesel commercial vehicles; however, a recent drive against diesel and greater use of compressed natural gas (CNG) seems to be having some impact. The Delhi Transport Department was ordered by a Supreme Court directive to convert from diesel fuel to CNG by April 2001, in an attempt to reduce pollution from diesel-fueled buses. The decision caused public transport chaos and angry demonstrations in New Delhi. The Supreme Court extended the deadline for the diesel ban several times, but in April 2002 it stood firm, forcing the Delhi government to pull around 6,000 diesel buses off the roads or face hefty fines, and causing commuter chaos in the city. India's two major bus manufacturers benefitted from the decision, which forced the local government to purchase around 1,000 new CNG-fueled buses [***13***]. Other cities are following suit.

India's demand for oil in the form of naphtha for electric power generation has grown at a phenomenal rate over the past decade [***14***]. In the long run, however, demand for naphtha in the power generation and industrial sectors is projected to decline, with natural gas claiming a larger share of the energy mix.

South Korea

South Korea consumed 2.1 million barrels of oil per day in 2001, compared with 1 million barrels per day in 1990. It is likely that the country will experience continued growth in oil demand, but at a slower rate than in the

1990s, as its transportation sector grows more slowly, pressures for greater energy efficiency increase, and the economy moves away from reliance on heavy industrial production.

Oil demand in South Korea fell drastically in 2001 as the result of an economic downturn. In 2002, economic recovery was apparent in the country, and oil demand was expected to begin rising as a result of stronger GDP and, to some extent, the surge in tourism that accompanied the World Cup soccer games in Seoul [*15*]. Oil demand in South Korea is projected to grow by 1.8 percent per year in the *IEO2003* reference case, reaching 3.3 million barrels per day in 2025. The transportation sector is expected to account for most of the increase, as demand growth slows in the industrial sector and remains flat in the residential and commercial sectors, where consumers are expected to continue switching to natural gas.

South Korea wants to use more CNG and less diesel fuel in its transportation sector. The government has announced a plan that would replace 20,000 diesel charter buses, 7,800 cross-country buses, and 2,200 express buses with CNG vehicles. About 10 percent of South Korea's metropolitan buses have already converted to CNG [*16*]. The Korean Ministry of Environment has not announced a decision on any clean-diesel option, which would include the ultra-low-sulfur diesel used during the World Cup soccer tournament in 2002.

Other Developing Asia

Oil demand in other developing Asia is projected to grow by 2.6 percent per year, from 5.5 million barrels per day in 2001 to 10.2 million barrels per day in 2025. Many poor countries in the region still depend heavily on biomass energy. The need to switch from biomass to petroleum products as the region's national economies grow will ensure that petroleum product consumption will grow substantially during the forecast period. In addition, market liberalization measures, such as the lowering of import tariffs within the Association of Southeast Asian Nations (ASEAN) Free-Trade Area (AFTA) are providing a further boost to the competitive economic environment and oil demand growth.

Middle East

Oil demand in the Middle East is projected to grow at an average annual rate of 2.1 percent, from 5.4 million barrels per day in 2001 to 8.9 million barrels per day in 2025. Growth in the region's oil consumption is expected to be tempered by aggressive moves into natural gas development and utilization being made by a number of countries. Oil's share in the energy mix was about 53 percent in 2001 and is projected to remain near that level through 2025. Coal, nuclear, and hydropower supplies in the region are limited, and the prospects for their development are minimal given the availability of oil and gas. Nevertheless, Iran is in the process of commissioning the Bushehr nuclear reactor, which was started in the 1970s, with the assistance of Russian expertise [*17*]. The reactor is expected to be completed by the end of 2004.

Iran and Saudi Arabia, the two largest oil consumers in the Middle East, each surpassed the million barrel per day consumption mark in the 1990s. Iran's domestic consumption of oil totaled at 1.5 million barrels per day in 2002, representing more than one-third of its oil production capacity [*18*]. The growth in demand for oil in Iran is supported by a large working-age population and heavily subsidized prices for transportation fuels.

In Saudi Arabia, the transportation sector and the massive petrochemical sector have been driving rapid growth in oil demand—mainly in the form of gasoline, diesel, liquefied petroleum gas (LPG), and naphtha—since the mid-1990s. Direct burning of crude oil in the power generation sector still takes place in Saudi Arabia, although the government plans to eliminate the practice before 2015. That will require Saudi Arabia to use 2.6 billion cubic feet per day of additional natural gas [*19*]. The Saudi government has launched a Strategic Gas Initiative, in which major oil companies (ExxonMobil and Shell) have been invited to explore and develop gas reserves that will feed five power plants and three desalination units, as well as petrochemical plants (see box on page 66 in the Natural Gas chapter).

Turkey, the largest economy in the Middle East, is struggling in the aftermath of its economic crisis, which began in February 2001 and left interest rates soaring. Over the forecast period, Turkey's economy is projected to grow by 4 percent per year, and its demand for oil is projected to grow by 3.1 percent per year, from 0.6 million barrels per day in 2001 to 1.3 million barrels per day in 2025.

Africa

In the past decade many African countries have introduced economic reforms under pressure from multilateral lending institutions [*20*]. Those reforms have started to show positive effects in the economy of the region, which in turn will encourage further growth in oil demand, particularly in the transportation sector. Oil demand in the power generation, industrial, and residential sectors is likely to remain relatively low due to the availability of alternatives to oil. South Africa, the largest economy in the region, is highly dependent on coal and will soon expand its use of gas with the startup of imports from Mozambique. During the outlook period, oil demand in Africa as a whole is projected to grow by 1.2 percent per year, to 3.5 million barrels per day in 2025.

Central and South America

IEO2003 projects stronger growth for oil demand in the developing world than in the industrial world but weaker growth than was projected in *IEO2002* projection. In particular, expectations for growth in Central and South America have been substantially lowered because of financial setbacks in Argentina and political unrest in Venezuela.

The lack of domestic savings, with the exception of Chile, is a significant limiting factor for potential economic growth in Central and South America. Many countries are in danger of serious economic turmoil in the face of their crippling debt-servicing requirements. In 2002, oil demand was hardest hit in Argentina, which plunged into depression after the country's economic collapse in December 2001. Fuel prices in Argentina have nearly doubled in 2002 after the devaluation of the local peso currency, causing sharp contraction of oil demand [***21***]. Colombia, Venezuela, and Uruguay all have tipped into recession, and investors have shied away from Brazil, the region's largest economy, fearing that the new, left-leaning government might reverse past privatization efforts.

The share of oil in total primary energy demand declined in Central and South America over the past decades with the development of large hydropower projects. Oil still accounts for one-half of the region's total energy use, however, and few new large-scale hydropower opportunities are expected to be developed over the forecast period. *IEO2003* projects that oil's share will decline slowly to 45 percent in 2025, mainly due to competition from natural gas in the electricity generation and industrial sectors. Oil demand in Central and South America is projected to grow by 2.1 percent per year, to 8.5 million barrels per day in 2025.

The Composition of World Oil Supply

In the *IEO2003* reference case, world oil supply in 2025 is projected to exceed the 2001 level by 41 million barrels per day. Increases in production are expected for both OPEC and non-OPEC producers; however, only about 39 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.

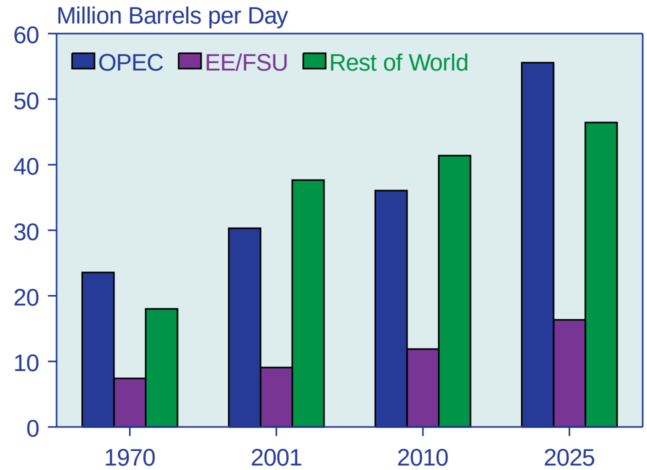
While the long-term outlook for non-OPEC supply remains optimistic, the low oil price environment of 1998 and early 1999 had a definite impact on exploration and development activity. By the end of 1998, drilling activity in North America had fallen by more than 25 percent from its level a year earlier. Worldwide, only the Middle East region registered no decline in drilling activity during 1998. In general, onshore drilling fell more sharply than offshore drilling. Worldwide, offshore rig utilization rates were generally sustained at levels better than 80 percent of capacity [***22***].

The reference case projects that about 61 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 37). The *IEO2003* estimates of OPEC production capacity to 2005 are slightly less than those projected in *IEO2002*, 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 low and high world oil price forecasts in this outlook do not assume such suggestions.

Reserves and Resources

Table 11 shows estimates of the conventional oil resource base by region out to the year 2025. Proved reserves are from the annual assessment of worldwide reserves published by *Oil & Gas Journal*. Reserve growth and undiscovered estimates are based on the *World Petroleum Assessment 2000* by the U.S. Geological Survey (USGS). The oil resource base consists of three categories: remaining proved reserves (oil that has been discovered but not produced); reserve growth (increases in proved reserves that occur over time as oil fields are

Figure 37. 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 (2003).

developed, produced, and are the beneficiaries of technological improvements; and undiscovered (oil that remains to be found through new field exploration). The information in Table 11 is derived from the USGS mean estimate, an average assessment over a wide range of uncertainty for reserve growth and undiscovered resources. The *IEO2003* oil production forecast is based on the USGS mean assessment.

Expansion of OPEC Production Capacity

It is generally acknowledged that OPEC members with large proved reserves and relatively low costs for expansion of production capacity can accommodate sizable increases in petroleum demand. In the *IEO2003* reference case, the production call on OPEC suppliers is projected to grow at a robust annual rate of 2.5 percent through 2025 (Table 12 and Figure 38). OPEC capacity utilization is expected to increase sharply after 2001, reaching 95 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 the *IEO2003* reference case, Iraq is assumed to maintain its

Table 11. Estimated World Oil Resources, 2000-2025
(Billion Barrels)

Region and Country	Proved Reserves	Reserve Growth	Undis-covered
Industrialized			
United States	22.45	76.03	83.03
Canada	180.02	12.48	32.59
Mexico	12.62	25.63	45.77
Japan	0.06	0.09	0.31
Australia/New Zealand	3.52	2.65	5.93
Western Europe	18.10	19.32	34.58
Eurasia			
Former Soviet Union	77.83	137.70	170.79
Eastern Europe	1.53	1.46	1.38
China	18.25	19.59	14.62
Developing Countries			
Central and South America	98.55	90.75	125.31
India	5.37	3.81	6.78
Other Developing Asia	11.35	14.57	23.90
Africa	77.43	73.46	124.72
Middle East	685.64	252.51	269.19
Total	**1,212.88**	**730.05**	**938.90**
OPEC	**819.01**	**395.57**	**400.51**
Non-OPEC	**393.87**	**334.48**	**538.39**

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

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

current oil production capacity of 3.1 million barrels per day into 2003. Iraq has indicated a desire to expand its production capacity aggressively, to about 6 million barrels per day, once the sanctions are lifted. Preliminary discussions of exploration projects have already been held with potential outside investors. Such a large increase in Iraqi oil exports would offset a significant portion of the price stimulus associated with the expected growth in oil demand.

Given the requirements for OPEC production capacity expansion implied by the *IEO2003* estimates, much attention has been focused on the oil development,

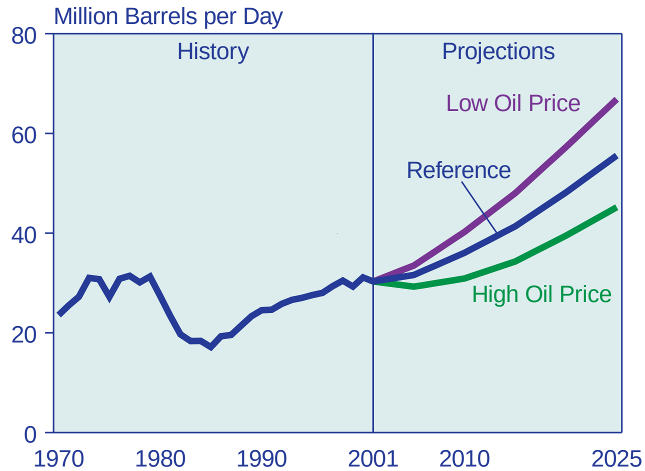
Table 12. OPEC Oil Production, 1990-2025
(Million Barrels per Day)

Year	Reference Case	High Oil Price	Low Oil Price
History			
1990	24.5	—	—
2001	30.3	—	—
Projections			
2005	31.6	29.3	33.5
2010	36.1	30.9	40.2
2015	41.4	34.3	48.0
2020	48.2	39.5	57.3
2025	55.6	45.2	66.9

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 (2003).

Figure 38. OPEC Oil Production in Three Oil Price 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 (2003).

production, and operating costs of individual OPEC producers. With Persian Gulf producers enjoying a reserve-to-production ratio that exceeds 89 years, substantial capacity expansion clearly is feasible.

Production costs in Persian Gulf OPEC nations are less than $2 per barrel, and the capital investment required to increase production capacity by 1 barrel per day is less than $5,600 [***23***]. Assuming the *IEO2003* low price trajectory, total development and operating costs over the entire projection period, expressed as a percentage of gross oil revenues, would be less than 21 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 $12,700 in some member nations; yet those producers can expect margins in excess of 34 percent on investments to expand production capacity over the long term, even in the low price case [***24***]. 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 in Venezuela 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 *IEO2003* 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 that the growth in world dependence on Persian Gulf oil will slow.

Non-OPEC Supply

The growth in non-OPEC oil supplies played a significant role in the erosion of OPEC's market share over the past two decades, as non-OPEC 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 *IEO2003* reference case, non-OPEC supply from proved reserves is expected to increase steadily, from 46.7 million barrels per day in 2001 to 62.8 million barrels per day in 2025 (Table 13).

There are several important differences between the *IEO2003* production profiles and those published in *IEO2002*:

- The U.S. production decline is somewhat less severe in the *IEO2003* projections as a result of higher oil price paths, technological advances yielding higher recovery rates, and lower costs for deepwater exploration and production in the Gulf of Mexico.
- The expected decline in North Sea production is slightly tempered, due to higher oil price paths coupled with enhanced subsea and recovery technologies.
- Resource development in the Caspian Basin region was expected to be delayed significantly in the *IEO2002* forecast due to significant geopolitical challenges and an expected lower price environment. In the *IEO2003* projections, Caspian output is expected to rise to almost 2.5 million barrels per day by 2005 and to increase steadily thereafter. There still remains a great deal of uncertainty about export routes from the Caspian Basin region.
- *IEO2002* anticipated moderate delays in the exploration and development of deepwater projects worldwide. Significant output from such projects was not anticipated until oil prices returned to and remained

Table 13. 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			
2005	49.1	50.2	47.8
2010	53.3	55.1	51.2
2015	57.0	59.6	54.1
2020	59.6	63.2	55.6
2025	62.8	67.8	58.1

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 (2003).

in the range of $22 to $28 per barrel for a significant period of time. With higher world oil price assumptions, output from deepwater projects in the U.S. Texas Gulf, the North Sea, West Africa, the South China Sea, Brazil, Colombia, and the Caspian Basin is accelerated in the *IEO2003* forecast by 2 to 3 years.

In the *IEO2003* forecast, the decline in North Sea production is slowed as a result of substantial improvement in field recovery rates. Production from Norway, Western Europe's largest producer, is expected to peak at about 3.4 million barrels per day in 2004 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 2.5 million barrels per day by the middle of this decade, followed by a decline to 1.4 million barrels per day by 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 output in Oman by more than 160,000 barrels per day, with only a gradual production decline anticipated after 2005. Current oil production in Yemen is expected to increase by at least 90,000 barrels per day in the next several years, and those levels should show little decline 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.

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 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 middle of this decade, their production is expected to reach almost 55,000 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 415,000 barrels per day by 2025.

Australia has made significant recent additions to its proved reserves, and it is possible that Australia will become a one million barrel per day producer by the middle of this decade. Malaysia shows little potential for any significant new finds, and its output is expected to peak at around 800,000 barrels per day early in this decade and then gradually decline to 680,000 barrels per day by 2025. Papua New Guinea continues to add to its reserve posture and is expected to achieve production volumes approaching 150,000 barrels per day by the middle 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 Myanmar, but significant output is not expected until late in this decade.

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 650,000 barrels per day within the decade and then show a modest decline 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 150,000 barrels per day over the next 2 years, and by the middle of the decade it is capable of becoming 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 350,000 barrels per day within the next few years.

Several West African producers (Angola, Cameroon, Chad, Congo, Gabon, and Ivory Coast) are expected to reap the benefits of substantial exploration activity, especially considering the recent rebound in oil prices. Angola is expected to become a million barrel per day producer early in this decade. Given the excellent exploration results, Angola could produce volumes of up to 3.2 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 1 million 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. Sudan and Equatorial Guinea are expected to produce significant volumes by the middle of this decade. Both could approach 500,000 barrels per day. Eritrea, Mauritania, Somalia, and South Africa also have some resource potential, but they are not expected to produce significant amounts until after 2005.

In North America, moderately rising U.S. output is expected to be complemented by significant production increases in Canada and Mexico. Canada's conventional oil output is expected to increase by more than 200,000 barrels per day over the next 2 years, mainly from

Newfoundland's Hibernia oil project, which could produce more than 155,000 barrels per day at its peak sometime in the next several years. Canada is projected to add an additional 500,000 barrels per day in output from a combination of frontier area offshore projects and oil from tar sands (see box below). Higher expected oil prices, technological advances, and lower costs for deepwater exploration and production in the Gulf of Mexico enhance the long-term U.S. production profile. Mexico is expected to adopt energy policies that will encourage the efficient development of its resource base. Expected production volumes in Mexico exceed 4.2 million barrels per day by the end of the decade and remain near that level through 2025.

With assumed higher oil prices, oil production in the FSU is expected to exceed 10 million barrels per day by 2005. The long-term production potential for the FSU is

And the Country with the Second Greatest Proved Oil Reserves Worldwide Is . . .

Six months ago, "Iraq" was the correct completion of the above phrase. Its 112.5 billion barrels of proved oil reserves was second only to Saudi Arabia's imposing 259.3 billion barrels. However, in the December 23, 2002, issue of the *Oil & Gas Journal*, proved oil reserves in Canada catapulted from an estimated 4.9 billion barrels in 2002 to an amazing 180 billion barrels in 2003. How was this possible? A methodology change by the *Oil & Gas Journal* now includes western Canada's oil sands in its definition of proved oil reserves. Heretofore, oil sands were considered "nonconventional" and were not counted as proved oil reserves; however, dramatic reductions in development and production costs have brought oil sands into the realm of economic viability. With today's technologies and oil prices, it is entirely appropriate to consider western Canada's vast oil potential as being commensurate with "conventional" crude oils.[a]

How much is there? It is estimated that there are about 1.7 trillion barrels of oil in the oil sands of Canada, and that about 15 percent (255 billion barrels) of the total oil in place is recoverable. Canada accounts for about 75 percent of the world's oil sand resources. Other countries and regions that have significant, but more modest, resources include the United States, China, the EE/FSU, the Caribbean Basin, and Pakistan. About 700 thousand barrels per day of Canadian oil sands are currently being produced. This supply is divided into two categories, "oil sands in situ" (often referred to as bitumen) and "oil sands mining." These two categories reflect the method of recovery. The bitumen is extracted by injecting very hot steam into the rock formation to heat up the oil, lower its viscosity, and allow it to flow more like conventional oil. Slightly more than half (about 400 thousand barrels per day) of Canadian oil sands production is derived from the more expensive "oil sands mining" method. Those deposits that are close enough to the surface are actually mined.

How much does recovery from oil sands cost? Supply costs are expressed as "full cycle" costs. They include all costs associated with exploration, development, and production; capital costs; operating costs; taxes and royalties; and a 10-percent real rate of return to the producer. Capital costs average $5 to $9 per barrel, and operating costs average $8 to $12 per barrel. Such costs are presented as a range, reflecting the variance in reservoir quality, depth, project size, and operating parameters. The remainder of the supply cost is dominated by the cleaning and upgrading methods that are required to turn a very low quality hydrocarbon into a more conventional oil that can be accepted by a refinery. Such methods include the removal of sulfur, heavy metals, and noncombustible materials, as well as conversion to a more hydrogenated and lighter hydrocarbon. These costs are typically in the $3 to $5 per barrel range. None of the aforementioned costs include transportation to market. This past summer, Suncor Energy opened the upgrading units of its Millennium Project in Alberta with production costs around $9 per barrel. The company's near-term goal is to lower production costs to $5.50 per barrel, which would make Suncor the lowest-cost oil producer in North America.[b]

What is the long-term outlook for production from oil sands? *IEO2003* projects that Canadian oil sand production in the reference case will increase to more than 2.2 million barrels per day by 2025. The projection assumes that world oil prices will moderate in the next few years and gradually increase to over $26.50 per barrel (all prices expressed in 2001 dollars) by the end of the forecast period. The *IEO2003* high oil price case (over $33 per barrel by 2025) shows Canadian oil sand production increasing to almost 2.5 million barrels per day by 2025. The only thing that prevents Canadian oil sands production from being considerably higher (both now and in the future) is the lack of transportation infrastructure (most likely pipeline capacity) for moving production to market. The United States is expected to import almost 1 million barrels per day of production from Canadian oil sands by 2025. If potential pipeline projects from Western Canada into PADDs II and IV materialize over the next two decades, the share of Canadian oil sand production going to U.S. imports could grow substantially.

[a]"Worldwide Look at Reserves and Production," *Oil & Gas Journal*, Vol. 100, No. 52 (December 23, 2002), pp. 114-115.
[b]National Energy Board, *Canada's Oil Sands: A Supply and Market Outlook to 2015* (Calgary, Alberta, October 2000), pp. 34-40.

still regarded with considerable optimism, especially for the resource-rich Caspian Basin region. The *IEO2003* reference case shows FSU output exceeding 15.9 million barrels per day by 2025, implying export volumes exceeding 6.7 million barrels per day. In China, oil production is expected to decline slightly to about 3.4 million barrels per day by 2025. China's import requirements are expected to be as large as its domestic production by 2012 and to continue growing as its petroleum consumption increases.

The *IEO2003* estimates for non-OPEC production potential 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 *IEO2003* price cases, no more than 15, 25, and 35 percent of the mean USGS 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 a relatively low price environment, 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 6.6 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.

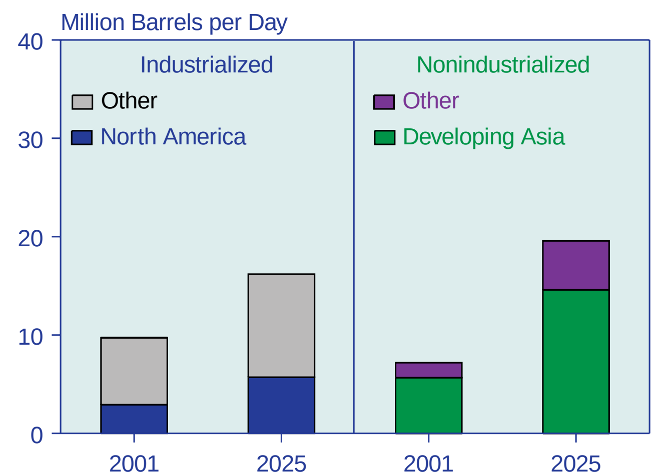
Worldwide Petroleum Trade in the Reference Case

In 2001, industrialized countries imported 16.1 million barrels of oil per day from OPEC producers. Of 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 (Table 14). By the end of the forecast period, OPEC exports to industrialized countries are estimated to be about 11 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 5 percent below their 2001 share, and the share of Persian Gulf exports going to the industrialized nations is projected to fall to about 12 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 16.8 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 5.9 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 almost double over the forecast period (Figure 39). 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 from Latin American producers, including Venezuela, Brazil,

Figure 39. 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, IEO2003 WORLD Model run IEO2003.B25 (2003).

Colombia, and Mexico. West African producers, including Nigeria and Angola, are also expected to increase their export volumes to North America. Caribbean Basin refiners are expected to account for most of the increase in North American imports of refined products.

With a moderate decline in North Sea production, Western Europe is expected to import increasing amounts from Persian Gulf producers and from OPEC member nations in both northern and western Africa. Substantial imports from the Caspian Basin are also expected. Industrialized Asian nations are expected to increase their already heavy 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 81.2 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.

Table 14. Worldwide Petroleum Trade in the Reference Case, 2001 and 2025
(Million Barrels per Day)

Exporting Region	Importing Region								Total Exports
	Industrialized				Nonindustrialized				
	North America	Western Europe	Asia	Total	Pacific Rim	China	Rest of World	Total	
	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	5.7	4.5	6.0	**16.2**	9.4	5.2	5.0	**19.6**	**35.8**
North Africa	0.4	2.9	0.0	**3.4**	0.6	0.2	0.6	**1.4**	**4.8**
West Africa	1.2	1.0	0.3	**2.5**	1.8	0.3	0.1	**2.2**	**4.7**
South America	4.3	0.3	0.1	**4.7**	0.4	0.0	0.3	**0.7**	**5.4**
Asia	0.1	0.0	0.2	**0.3**	1.5	0.2	0.1	**1.8**	**2.1**
Total OPEC	**11.8**	**8.7**	**6.7**	**27.1**	**13.6**	**5.9**	**6.0**	**25.6**	**52.7**
Non-OPEC									
North Sea	0.7	3.4	0.0	**4.0**	0.1	0.0	0.2	**0.3**	**4.3**
Caribbean Basin	2.5	0.4	0.1	**3.0**	0.5	0.0	1.0	**1.5**	**4.5**
Former Soviet Union	0.8	4.9	0.8	**6.5**	0.6	1.4	1.4	**3.4**	**9.9**
Other Non-OPEC	12.6	2.8	0.6	**16.0**	4.4	0.4	2.5	**7.3**	**23.3**
Total Non-OPEC	**16.5**	**11.5**	**1.5**	**29.5**	**5.5**	**1.8**	**5.1**	**12.5**	**42.0**
Total Petroleum Imports	**28.3**	**20.2**	**8.1**	**56.6**	**19.1**	**7.8**	**11.2**	**38.1**	**94.6**

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, IEO2003 WORLD Model run IEO2003.B25 (2003).

Other Views of Prices and Production

Several oil market analysis groups produce world oil price and production forecasts. Table 15 compares the *IEO2003* world oil price projections with similar forecasts from the International Energy Agency (IEA), Petroleum Economics, Ltd. (PEL), Petroleum Industry Research Associates (PIRA), Altos Partners (Altos), Energy and Environmental Analysis, Inc. (EEA), Natural Resources Canada (NRCan), Global Insight, Inc. (GII), and Deutsche Banc Alex.Brown (DBAB).

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. High oil prices followed the ability of OPEC to maintain production quotas in 2000, which supported sustained high prices throughout the year. Finally, 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, disruption of Venezuela's oil exports, a colder than expected winter in North America, and low storage levels in the United States. By the first quarter of 2003, oil prices had neared $40 per barrel (nominal dollars).

The current oil price projections for 2005 range from PEL's $21.21 per barrel (constant 2001 U.S. dollars) to *IEO2003*'s $23.27 per barrel. The NRCan forecast is the earliest: NRCan's projection was originally formulated in 1997 (but reaffirmed in 2002). Nevertheless, NRCan's forecast falls well within the range defined by the other forecasts. Five of the eight forecasts—GII, IEA, PEL, DBAB, and EEA—fall below the range defined by the *IEO2003* high and low world oil price cases in 2005, demonstrating the volatility of the oil markets in the wide range of price projections in this early year of the forecast.

The PEL price forecast series may be considered an outlier relative to the rest of the forecasts. It is the only series among the set of forecasts that is based on Brent oil prices; they fall consistently below those of the *IEO2003* low price path through 2015, when the PEL time series ends. If the PEL series is omitted, the range of prices among the remaining series is much smaller in 2015, $7 per barrel, with PIRA at the high end of the range ($26.32 per barrel) and DBAB at the low end ($19.34 per barrel). At the end of the forecast period, the uncertainty among the forecasters as measured by the difference between highest and lowest expected prices climbs to $12.43 per barrel, with the range defined by the Altos ($31.61 per barrel) and DBAB ($19.18 per barrel) forecasts.

The *IEO2003* price projections are generally at the high end of the spectrum of price forecasts across the

Table 15. Comparison of World Oil Price Projections, 2005-2025
(2001 Dollars per Barrel)

Forecast	2005	2010	2015	2020	2025
IEO2003					
Reference Case	23.27	23.99	24.72	25.48	26.57
High Price Case	28.65	32.51	32.95	33.02	33.05
Low Price Case	22.04	19.04	19.04	19.04	19.04
Altos	22.64	23.40	25.58	27.90	31.61
GII	20.80	21.70	23.76	25.39	—
IEA	21.47	21.47	23.52	25.56	27.61
PEL	21.21	18.46	17.47	—	—
PIRA	22.43	23.33	26.32	—	—
NRCan	22.28	22.28	22.28	22.28	—
DBAB	19.04	18.94	19.34	19.07	19.18
EEA	20.98	20.47	19.98	19.50	—

Notes: *IEO2003* projections are for average landed imports to the United States. Altos, PIRA, and NRCan projections are for West Texas Intermediate crude oil at Cushing. GII, DBAB, 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: ***IEO2003*:** Energy Information Administration, *Annual Energy Outlook 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003). **Altos:** Altos Partners, World Oil Model, e-mail from Tom Choi (October 9, 2002). **GII:** Global Insight, Inc., *U.S. Energy Price Outlook, Autumn/Winter 2002* (Lexington, MA, December 2002), p. 12. **IEA:** International Energy Agency, *World Energy Outlook 2002* (Paris, France, September 2002), p. 39. **PEL:** Petroleum Economics, Ltd., *World Long Term Oil and Energy Outlook* (London, United Kingdom, June 2002), p. 47. **PIRA:** PIRA Energy Group, *Retainer Client Seminar* (New York, NY, October 2002), Table II-3. **NRCan:** Natural Resources Canada, *Canada's Energy Outlook, 1996-2020*, Annex C2 (Ottawa, Ontario, Canada, April 1997) (reaffirmed in August 2002). **DBAB:** Deutsche Banc Alex.Brown, Inc., "World Oil Supply and Demand Estimates," e-mail from Adam Sieminski (January 17, 2003). **EEA:** Energy and Environmental Analysis, Inc., EEA Compass Service: October 2002 Base Case.

2005-2025 time period, with a few exceptions. PIRA's $26.32 price forecast for 2015 is higher than the *IEO2003* estimate of $24.72. The Altos forecasts for 2015-2025 are higher than the *IEO2003* reference case projections, as are the IEA price estimates for 2020 and 2025. 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 $21.47 per barrel in 2010 to $29.65 per barrel in 2030. A simple interpolation results in oil prices in 2015 of about $23.52 per barrel and in 2025 of $27.61 per barrel, placing the IEA prices slightly below the *IEO2003* estimate of $24.72 per barrel in 2015 but above the *IEO2003* estimate in 2025.

The Altos price projections follow a particularly steep upward path over the 2005 to 2025 time horizon. Whereas the Altos prices in 2005 are $0.63 per barrel lower than those in the *IEO2003* reference case, by 2015 they are $0.86 per barrel higher than the *IEO2003* prices. By 2025, the Altos prices are $5.04 per barrel higher than the *IEO2003* projection.

The price forecasts are influenced by differing views of the projected composition of world oil production. Two factors are of particular importance: (1) expansion of OPEC oil production and (2) the timing of a recovery in EE/FSU oil production. All the forecasts agree that the recovery of EE/FSU production will be fairly slow, although most are somewhat more optimistic about EE/FSU production development than they were last year.

High world oil prices in 2002 and into the first part of 2003, along with accelerating economic recovery in Russia, currently the largest oil producer in the EE/FSU region, no doubt have influenced the production forecasts for the EE/FSU. Nevertheless, only DBAB projects that the share of EE/FSU production will rise above 15 percent over the course of the projection period. DBAB estimates that EE/FSU production will rise to 18 percent of total world oil supply by 2025 (Table 16). GII is the least optimistic about recovery in the region, and its projected share for the EE/FSU remains at 11 percent throughout the 2005-2025 time period. The other four production forecasts expect the EE/FSU share of world oil production to vary between 13 and 15 percent. *IEO2003* projects that the EE/FSU share of production will reach 14 percent of the world total in 2015 and remain at that level through 2025.

The forecasts that provide projections through 2020 (*IEO2003*, GII, DBAB, and IEA) all expect OPEC to provide incremental production of between 17 and 20 million barrels per day between 2001 and 2020 (Table 16). There is more variation in expectations among these four forecasts for the "other" non-OPEC suppliers. GII expects a substantial increase of 13.1 million barrels per day of supply from other suppliers, whereas IEA expects a decline of 5.0 million barrels per day in production from other non-OPEC sources. IEA projects that the "other" share of world oil production will fall to 31 percent by 2020 while the OPEC share increases to 48 percent. In contrast to GII, *IEO2003* expects more moderate growth in other non-OPEC supply, at 8.0 million barrels per day from 2001 to 2020. DBAB expects growth of 3.5 million barrels per day.

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Table 16. 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							
2001	39	13	48	30.4	9.8	37.1	**77.0**
Projections							
2005							
IEO2003	39	12	48	31.6	10.0	39.1	**80.7**
GII[a]	37	10	49	30.6	8.7	40.6	**83.2**
PEL	37	13	47	30.4	10.3	38.4	**81.1**
PIRA	34	13	53	28.4	10.5	43.5	**82.4**
DBAB	37	14	47	30.1	11.4	37.7	**80.8**
2010							
IEO2003	40	13	46	36.1	11.9	41.3	**89.3**
GII[a]	38	11	48	34.7	10.0	44.5	**89.1**
IEA[b]	40	14	39	35.9	12.7	35.1	**88.9**
PEL	40	13	45	35.6	11.6	39.7	**89.1**
PIRA	35	15	50	32.1	13.3	46.1	**91.5**
DBAB	41	16	41	36.5	14.1	36.4	**89.1**
2015							
IEO2003	42	14	44	41.4	13.6	43.4	**98.4**
GII[a]	38	11	47	39.3	11.5	48.2	**102.6**
PEL	46	13	39	44.4	12.7	37.6	**97.0**
PIRA	38	15	47	37.5	15.3	46.7	**99.5**
DBAB	42	17	39	41.5	16.3	38.1	**98.3**
2020							
IEO2003	45	14	42	48.2	14.8	44.8	**107.8**
GII[a]	42	11	44	47.3	12.0	49.9	**112.7**
IEA[b]	48	13	31	50.2	13.9	31.8	**104.1**
DBAB	43	17	37	46.9	18.9	40.3	**108.7**
2025							
IEO2003	47	14	39	55.6	16.3	46.4	**118.3**
DBAB	45	18	35	54.3	21.9	42.0	**121.1**

[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 DBAB 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: ***IEO2003*****:** Energy Information Administration, System for the Analysis of Global Energy Markets (2003). **GII:** Global Insight, Inc., *Oil Market Outlook: Long-Term Focus, Spring/Summer 2002* (Lexington, MA, 2002), p. 30. **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, June 2002), p. 47. **PIRA:** PIRA Energy Group, *Retainer Client Seminar* (New York, NY, October 2002), Table II-3. **DBAB:** Deutsche Banc Alex.Brown, Inc., "World Oil Supply and Demand Estimates," e-mail from Adam Sieminski (January 17, 2003).

19. Fesharaki Associates Consulting & Technical Services (FACTS) and East West Consultants International (EWCI), *Middle East Petroleum Databook* (Honolulu, Hawaii, Fall 2002), p. 11.

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Natural Gas

Natural gas is the fastest growing primary energy source in the IEO2003 forecast. Consumption of natural gas is projected to nearly double between 2001 and 2025, with the most robust growth in demand expected among the developing nations.

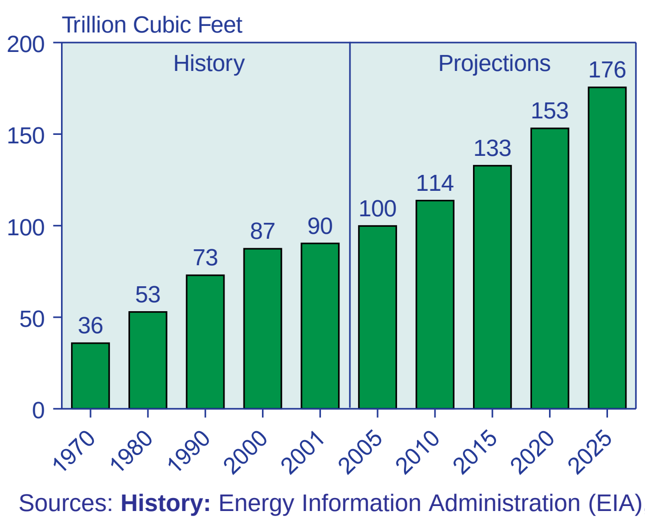
Natural gas is expected to be the fastest growing component of world primary energy consumption in the *International Energy Outlook 2003* (*IEO2003*) reference case. Consumption of natural gas worldwide is projected to increase by an average of 2.8 percent annually from 2001 to 2025, compared with projected annual growth rates of 1.8 percent for oil consumption and 1.5 percent for coal. Natural gas consumption in 2025, at 176 trillion cubic feet, is projected to be nearly double the 2001 total of 90 trillion cubic feet (Figure 40). The natural gas share of total energy consumption is projected to increase from 23 percent in 2001 to 28 percent in 2025.

The most robust growth in natural gas demand is expected among the nations of the developing world, where overall demand in the reference case rises by 3.9 percent per year between 2001 and 2025. The level of natural gas use in the developing world by 2025 is projected to be two and one-half times the 2001 level (Figure 41). Much of the growth in the region is expected to fuel electricity generation, but infrastructure projects are also underway for natural gas to displace polluting home heating and cooking fuels in major urban areas, such as Beijing and Shanghai.

Industrialized countries, where natural gas markets are most mature, also are projected to increase their reliance on natural gas. Over the next 24 years, demand for natural gas in the industrialized world is expected to increase by 2.2 percent annually, almost twice the rate of increase projected for oil. Among the industrialized regions, North America is expected to have the largest increment in natural gas use between 2001 and 2025, at 19 trillion cubic feet per day (Figure 42). The United States alone accounts for 66 percent of the total North American increment in gas consumption. In the United States, natural gas demand is expected to rise by 1.8 percent annually, mainly for electricity generation. Of the new generating capacity projected for the United States, 80 percent is expected to be natural-gas-fired combined-cycle or combustion turbine technology, including distributed generation capacity.

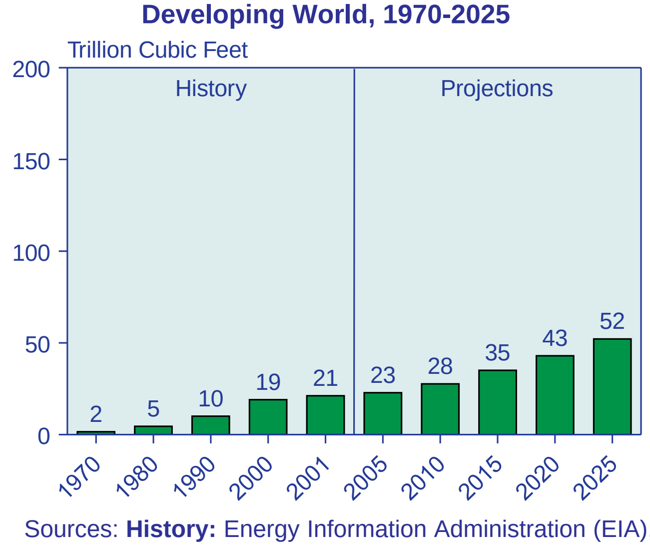
Rapid growth in natural gas use is projected for Mexico, at 6.1 percent per year over the projection period. The industrial and electric utility sectors are expected to account for most of the growth, and some increase for residential and commercial sector use are expected as a result of the 1995 privatization of the transmission and

Figure 40. 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 (2003).

Figure 41. Natural Gas Consumption in the Developing World, 1970-2025



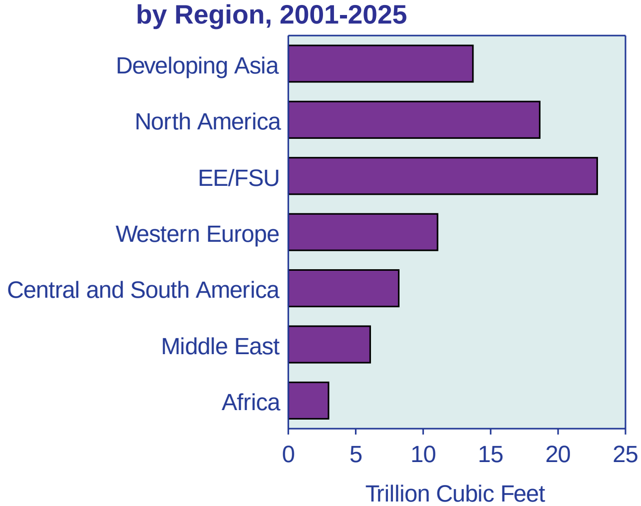
Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2003).

distribution sector, which has brought natural gas service to a number of cities for the first time.

Western Europe is also expected to expand its use of natural gas strongly over the projection period, at an average annual rate of 2.4 percent. Liberalization of natural gas markets in the European Union has been underway since the passage of the Natural Gas Directive in 1998, and in a majority of the member countries, natural gas infrastructures are expected to be fully open to third-party access by 2008. Increases in natural gas use for electricity generation are expected in many Western European countries, replacing many old coal-fired generators and nuclear power plants set to retire in the coming decades. Total natural gas consumption in Western Europe is expected to increase from 14.8 trillion cubic feet in 2001 to 25.9 trillion cubic feet in 2025.

In Eastern Europe and the former Soviet Union (EE/FSU), natural gas consumption is expected to increase by 2.9 percent annually between 2001 and 2025. The fastest rates of growth in the region are projected for the countries of Eastern Europe, where economic recovery has been underway since the collapse of the Soviet Union, and the economies of the region continue to align with their wealthier Western European neighbors. Eastern Europe's demand for natural gas is expected to grow by 4.6 percent per year in the forecast. An infrastructure that is fast becoming integrated with Western Europe supports the growth in East European gas use. In the FSU, natural gas demand is expected to increase at a somewhat slower pace, 2.6 percent per year. There has been some progress in restructuring the natural gas markets in the FSU, and several years of positive economic growth indicate that sustained economic recovery is now underway.

Figure 42. 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 (2003).

The amount of natural gas traded across international borders continues to grow, increasing from barely 19 percent of the world's consumption in 1995 to 23 percent in 2001 [***1***]. Pipeline exports grew by 39 percent and liquefied natural gas (LNG) trade grew by 55 percent between 1995 and 2001. Numerous international pipelines are either planned or already under construction. Projected increases in world natural gas consumption will require bringing new gas resources to market. 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 for LNG.

The economics of transporting natural gas to demand centers currently depend on the market price, and the pricing of natural gas is not as straightforward as the pricing of oil. More than 50 percent of the world's oil consumption is traded internationally, whereas natural gas markets tend to be more regional in nature, and prices can vary considerably from country to country. In Asia and Europe, for example, LNG markets are strongly influenced by oil product markets rather 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

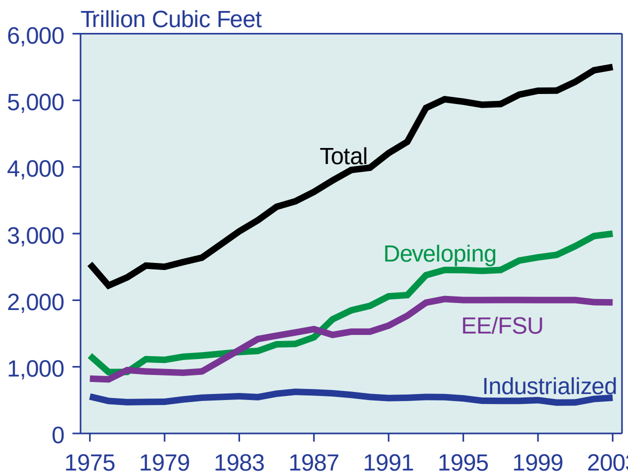
Since the mid-1970s, world natural gas reserves have generally trended upward each year (Figure 43). As of January 1, 2003, proved world natural gas reserves,[3] as reported by *Oil & Gas Journal*, were estimated at 5,501 trillion cubic feet, 50 trillion cubic feet more than the estimate for 2002. Most of the increase is attributed to developing countries, where gas reserves have increased by 37 trillion cubic feet since last year's survey. Natural gas reserves in the industrialized countries also increased between 2002 and 2003, by 18 trillion cubic feet. EE/FSU reserves declined by 4 trillion cubic feet—primarily because of lowered estimates for Turkmenistan, where reserves declined by 30 trillion cubic feet. The decrement was largely offset by the enormous upward revision to Azerbaijan gas reserves in this year's survey, from 4 trillion cubic feet in 2002 to 30 trillion cubic feet in 2003.

[3]Proved Reserves, as reported by the *Oil & Gas Journal*, are estimated quantities that can be recovered under present technology and prices. Figures reported for Canada and the former Soviet Union, however, include reserves in the probably 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 2002 are not likely to be reflected in the reported reserves.

Most (about 71 percent) of the world's natural gas reserves are located in the Middle East and the EE/FSU (Figure 44), with Russia and Iran together accounting for about 45 percent of the world's natural gas reserves (Table 17). Reserves in the rest of the world are fairly evenly distributed on a regional basis.

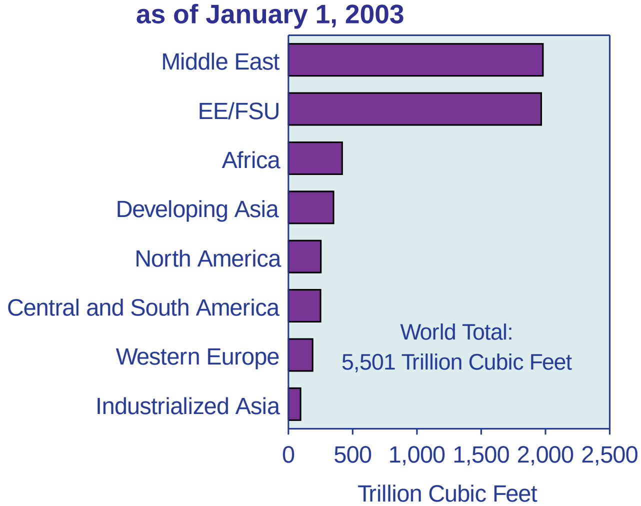
Despite high rates of increase in natural gas consumption, particularly over the past decade, most regional reserves-to-production ratios have remained high. Worldwide, the reserves-to-production ratio is estimated at 61.9 years [***2***]. Central and South America has a reserves-to-production ratio of 71.6 years, the FSU 78.5 years, and Africa 90.2 years. The Middle East's reserves-to-production ratio exceeds 100 years.

Figure 43. World Natural Gas Reserves by Region, 1975-2003



Sources: **1975-1993:** "Worldwide Oil and Gas at a Glance," *International Petroleum Encyclopedia* (Tulsa, OK: PennWell Publishing, various issues). **1994-2003:** *Oil & Gas Journal* (various issues).

Figure 44. World Natural Gas Reserves by Region as of January 1, 2003



Source: "Worldwide Look at Reserves and Production," *Oil & Gas Journal*, Vol. 100, No. 52 (December 23, 2002), pp. 114-115.

The largest expansion in worldwide natural gas reserves between 2002 and 2003 occurred in Western Europe, where 31 trillion cubic feet was added to the region's reserve base. This increment in reserves is entirely attributable to Norway, where reserves grew by 33 trillion cubic feet as a result of recent new gas finds, including Statoil's Tyrihans South discovery of oil and gas in the Norwegian Sea [***3***]. The increment in Norwegian reserves more than offset minor decrements in other Western European countries—including the United Kingdom, the Netherlands, and Germany—and placed Norway among the top 20 countries with respect to proven natural gas reserves.

U.S. proven gas reserves increased by 6 trillion cubic feet and Canadian reserves increased by less than 1 trillion cubic feet, but Mexico's reserves dropped by nearly 21 trillion cubic feet between 2002 and 2003. Petroleos Mexicanos revised its estimate of national oil and natural gas reserves downward in September 2002 to comply with U.S. Securities and Exchange Commission filing guidelines [***4***]. Natural gas reserves in industrialized Asia increased slightly in 2003, by about 1 trillion cubic feet, as a result of new finds in New Zealand.

Table 17. World Natural Gas Reserves by Country as of January 1, 2003

Country	Reserves (Trillion Cubic Feet)	Percent of World Total
World	**5,501**	**100.0**
Top 20 Countries	**4,879**	**88.7**
Russia	1,680	30.5
Iran	812	14.8
Qatar	509	9.2
Saudi Arabia	224	4.1
United Arab Emirates	212	3.9
United States	183	3.3
Algeria	160	2.9
Venezuela	148	2.7
Nigeria	124	2.3
Iraq	110	2.0
Indonesia	93	1.7
Australia	90	1.6
Norway	77	1.4
Malaysia	75	1.4
Turkmenistan	71	1.3
Uzbekistan	66	1.2
Kazakhstan	65	1.2
Netherlands	62	1.1
Canada	60	1.1
Egypt	59	1.1
Rest of World	**622**	**11.3**

Source: "Worldwide Look at Reserves and Production," *Oil & Gas Journal*, Vol. 100, No. 52 (December 23, 2002), pp. 114-115.

Among the regions of the developing world, Africa and Asia had the largest revisions in proved natural gas reserves between 2002 and 2003. In Africa, the entire increment of 23 trillion cubic feet in gas reserves is attributable to Egypt, where a marked increase in exploration activity over the past few years has resulted in a substantial increase in gas reserves, including finds in the Western Desert, Gulf of Suez, Mediterranean Sea, and Nile Delta [***5***]. Developing Asia saw an increase in reserves of 11 trillion cubic feet over the past year. Among the developing Asian countries, the greatest increases in proven reserves were in China and India, where reserves grew by 5 trillion cubic feet and 4 trillion cubic feet, respectively. Modest increases were made in Pakistan, the Philippines, and Thailand.

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 4,839 trillion cubic feet (Figure 45), which is approximately double the worldwide cumulative consumption forecast in *IEO2003*. A further 3,000 trillion cubic feet is estimated to be 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 former Soviet Union, 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.

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

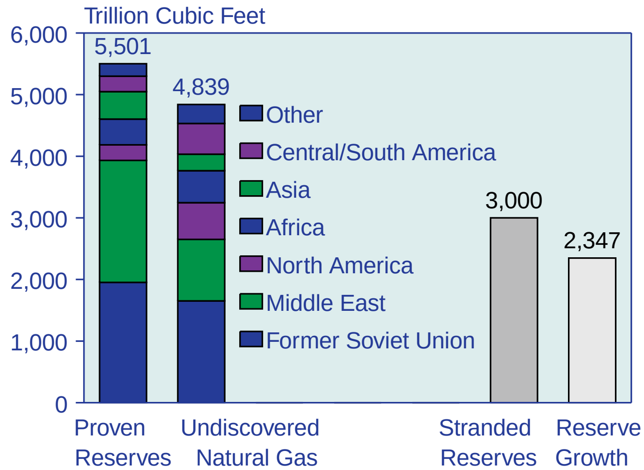
North America

Natural gas consumption in North America is projected to grow by 2.2 percent per year on average between 2001 and 2025 (Figure 46). Demand for gas is projected to increase in all three countries of the region (Canada, Mexico, and the United States), with the highest rate of growth projected for Mexico. The expanding gas infrastructure in Mexico is expected to be particularly focused on providing gas to electric power stations. The Canadian and U.S. natural gas markets are already well integrated. As additional infrastructure is built in Mexico and between Mexico and the United States, it is expected that an increasingly integrated natural gas market will serve the entire region.

United States

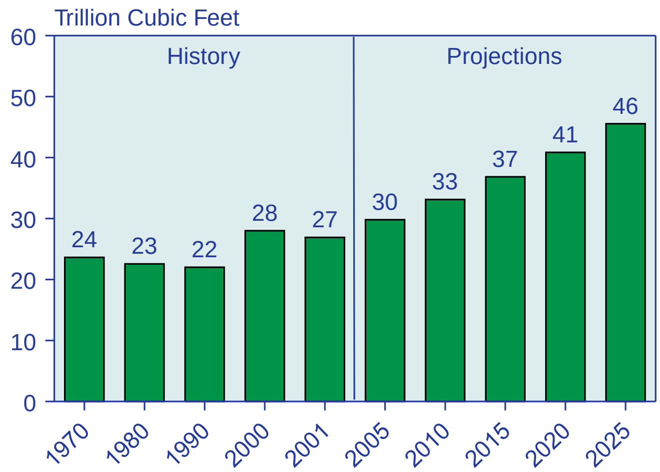
The United States continues to be the largest producer and consumer of natural gas in North America. Total

Figure 45. World Natural Gas Resources by Region as of January 1, 2003



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. 100, No. 52 (December 23, 2002), pp. 114-115.

Figure 46. Natural Gas Consumption in North America, 1970-2025



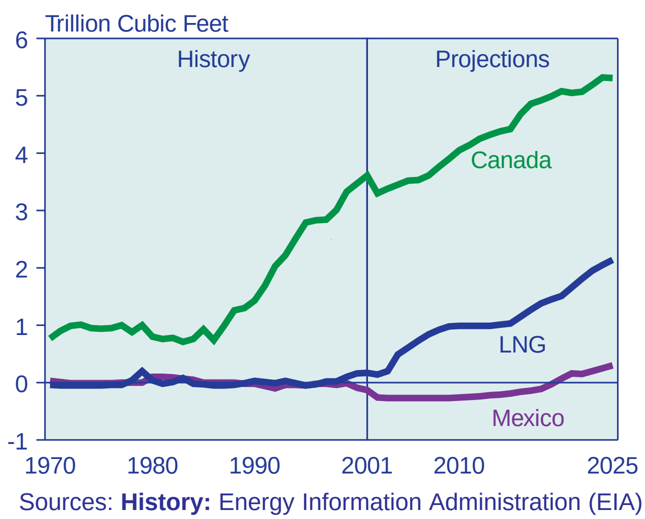
Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2003).

U.S. natural gas consumption is projected to increase from 22.6 trillion cubic feet in 2001 to 34.9 trillion cubic feet in 2025. The largest increase in U.S. gas consumption is expected to occur in the electricity generation sector, which is projected to consume 10.6 trillion cubic feet in 2025 [*6*]. Both U.S. production and imports of natural gas are expected to grow. In 2025, net Canadian gas imports are expected to provide 15 percent of total U.S. consumption, which is about the same proportion being supplied by Canada today. This projection of Canadian gas exports to the United States expects that the MacKenzie Delta gas pipeline will begin operation in 2016. An additional 6 percent of total U.S. natural gas consumption, or 2.1 trillion cubic feet, is projected to be supplied by LNG imports (Figure 47). Mexico is expected to become a net exporter of natural gas to the United States after 2019, assuming the construction of an LNG regasification terminal in Baja, Mexico.

In 2000 and 2001, new U.S. gas discoveries replaced 99.6 and 115.1 percent of the natural gas produced during those years [*7*]. Gas producers, however, are not so sanguine about the future. There has been considerable discussion within the industry that a lack of good gas drilling prospects might lead to future U.S. supply problems [*8*].

A number of recent legislative proposals and market developments in the United States may have long-term implications for the U.S. natural gas market. On the legislative side, during much of 2002, major energy bills were debated in the U.S. Congress, particularly the House of Representatives Bill 4 (H.R. 4) and Senate Bill 1766 (S. 1766). S. 1766 originally proposed a Federal loan guarantee for an Alaskan gas pipeline, which would have guaranteed 80 percent of the principal of any loan made to finance its construction. The loan guarantee was capped at $10 billion. A later amendment to S. 1766 would have provided additional financial support for the Alaska gas pipeline in the form of an income tax credit, which would have become effective when the average monthly price of natural gas at AECO C Hub in Alberta fell below $3.25 per million Btu. Any tax credit collected by shippers would then be subject to being paid back when the benchmark price went above $4.88 per million Btu. H.R. 4 called for the establishment of a Federal leasing program that would open the Alaskan National Wildlife Refuge (ANWR) to oil and gas production. Both the House and Senate bills called for the restoration of Section 29 tax credits for coalbed methane production. Deadlock on a host of issues associated with these bills prevented the Congress from passing any comprehensive energy bill during its last session.

Figure 47. 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 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table A13.

On January 10, 2003, the U.S. Bureau of Land Management released the "Final Environmental Impact Statement and Proposed Plan Amendment for the Powder River Basin Oil and Gas Project." This long-delayed Environmental Impact Statement (EIS) has constrained coalbed methane development in Wyoming's Powder River Basin, because development in the area could not proceed without approval of the EIS [*9*]. Although a number of issues were addressed in the EIS, the primary issue associated with coalbed methane production is the disposal of water produced in conjunction with the natural gas. Currently, large amounts of water are being discharged directly on the surface rather than being reinjected into the ground. Coalbed methane producers are concerned that a reinjection requirement might be uneconomical. In contrast, land owners are concerned that the surface discharge of water will contaminate streams and aquifers with salty water. Although the EIS contains a preferred plan for water disposal, it provides only an analytical basis for Government decisions. In the formation of those decisions, the issue of water disposal is likely to remain contentious.

Access to Federal lands has been a perennial political issue for the natural gas industry, because a considerable portion of the entire U.S. gas resource base both onshore and offshore is under Federal lease jurisdiction. Some of the gas resources under Federal lands are completely precluded from development, and development of others is constrained by Federal lease stipulations [*10*]. In November 2000, Congress passed the Energy Policy and Conservation Act Amendments of 2000 (EPCA), which required Federal agencies to conduct an inventory of oil and gas resources beneath onshore Federal lands. The inventory was to quantify the volumes of oil and gas resources on Federal lands and to determine the nature and extent of any restrictions or impediments to their development. Because most of the Federal lands affected are located in the Rocky Mountain States, the EPCA Federal inventory focused exclusively on five major petroleum basins in the region. In January 2003, the results of the Federal oil and gas resource inventory were published [***11***]. The study found that of the 138.5 trillion cubic feet estimated to be under Federal lands in the Rocky Mountain region, approximately 11.5 percent is under Federal lands where no leasing is permitted, and another 26 percent is subject to lease restrictions. The remaining 62.5 percent can be leased under standard Federal lease terms with no restrictions [***12***].

On December 18, 2002, the U.S. Federal Energy Regulatory Commission (FERC) announced a new regulatory policy for LNG regasification terminals [***13***]. The FERC announced that new U.S. LNG terminals would no longer be subject to the Commission's open-access and cost-of-service regulations. Owners would be permitted to operate new LNG terminals on a private contract basis and charge market-based rates. The regulatory change was requested by LNG project sponsors, who wanted assurance that LNG supplies produced overseas by their corporate subsidiaries could be guaranteed access to the U.S. market through their proprietary terminals. The FERC's decision also reduces the financial risk associated with new LNG facilities, because their profitability and the profitability of parent companies' upstream facilities (i.e., overseas gas production and liquefaction facilities and LNG tankers) will no longer be constrained by a tariff rate cap. Collectively, these changes are expected to reduce LNG project risk and thus enhance the financial incentive to build new LNG facilities.

Although the financial risk of building new LNG terminals has been reduced by the new FERC policy, other industry developments have impaired the financial circumstances of several LNG project sponsors. For example, Enron Corporation filed for Chapter 11 reorganization in December 2001, and Dynegy Inc. reported a $2.8 billion net loss for 2002. Similarly, AES Corporation reported a 2002 net loss of $3.5 billion, and El Paso Corporation's financial difficulties are reflected in its decision to sell $3.4 billion of assets during 2003 [***14***]. These four financially challenged companies are unlikely to build the LNG facilities they had proposed. The four companies had previously announced intentions to build approximately 1.6 trillion cubic feet of new LNG regasification capacity in the United States [***15***].

Another potential casualty of recent financial problems is the future implementation of the El Paso "Energy Bridge" LNG concept. The construction of new onshore LNG terminals is expected to encounter considerable local political opposition. Such opposition, for example, was cited as one reason for Shell U.S. Gas and Power's decision to end its participation in a proposal to build the Mare Island LNG terminal [***16***]. The El Paso "Energy Bridge" concept was to build floating offshore docks that would allow LNG tankers to unload their cargoes out of sight of land. It was hoped that the approach would eliminate the political opposition associated with onshore facilities. Now that El Paso has decided to exit the LNG business, this innovative approach to building and operating new LNG terminals might go untested for some time.

Many large U.S. corporations have abandoned or reduced activities in natural gas trading, marketing, and brokering as a result of financial difficulties. Industry participants are concerned that the exit of gas traders will reduce the liquidity and therefore the transparency of U.S. natural gas markets, leading to increased price volatility and uncertainty [***17***]. Increased uncertainty about future natural gas prices, in turn, would increase the cost of capital for natural gas exploration and development [***18***].

Another issue that has arisen is whether a gas pipeline will be built to transport stranded Alaskan North Slope gas to the lower 48 gas consumption market. Interest in building an Alaskan gas pipeline was revived during the winter of 2000-2001, when natural gas prices were relatively high. In May 2002, BP, ExxonMobil, and ConocoPhillips released a joint study that evaluated the economics of constructing a gas pipeline from the Alaska North Slope to the lower 48 States [***19***]. The primary conclusions of the financial analysis were that a pipeline built from the North Slope Alaska to Chicago would cost approximately $18.6 to $19.4 billion dollars[4] to build (depending on the route used), and that the pipeline's transportation tolls to the lower 48 States would be between $2.31 to $2.39 per thousand cubic feet. Even though North Slope oil and gas producers continue to be interested in building an Alaskan gas pipeline, as witnessed by their continued efforts to reduce pipeline capital costs and regulatory uncertainty, there are no current indications that the pipeline's construction would be completed before 2010 [***20***].

Canada

Natural gas consumption in Canada is projected to grow at a rate of 2.3 percent per year between 2001 and 2025. In 2000, approximately 53 percent of Canada's dry gas production of 6.3 trillion cubic feet was exported to the United States [***21***]. By 2025, net exports of natural gas from Canada to the United States are projected to be 5.3 trillion cubic feet in the *IEO2003* reference case, and Canada's own consumption is projected to be 5.0 trillion cubic feet [***22***]. The Canadian National Energy Board (NEB) estimates that Canada has an undiscovered potential conventional gas resource base of between 389 and 460 trillion cubic feet [***23***].

[4] The cost estimates include the cost of constructing a natural gas treatment plant and a natural gas liquids extraction plant.

Although Canada's natural gas resources appear adequate for the period through 2025, some concerns have been raised about the future viability of finding and developing conventional gas resources. Even though new Canadian gas discoveries in 2001 replaced 106 percent of its gas production, some producers are concerned that depletion of conventional gas resources might cause development costs to escalate rapidly, especially in the Western Canadian Sedimentary Basin (WCSB), which is the primary source of Canada's conventional gas supplies [**24**]. A recent NEB report [**25**] summarizes the situation in the following manner:

> *An average gas recovery for 2001 connections will be less than 25 percent of the average gas recovery for 1995 connections. These large reductions in gas recovery per connection correlate with the diminishing gas supply response to increasing drilling activity. To compensate for the lower recovery per connection, an increasing number of wells has to be drilled to increase or even maintain overall natural gas production from the WCSB.*

Concern about WCSB conventional gas resources has also been raised by the rapid production decline of the Ladyfern gas field, which is thought to contain 1 trillion cubic feet of recoverable gas and is the largest onshore gas accumulation found in North America over the past 15 years. By the close of March 2002, 40 Ladyfern wells were producing 785 million cubic feet per day, 5 percent of Canada's natural gas stream. In June 2002, however, the field was producing only 650 million cubic feet per day, and by the end of 2002 it was expected to be producing only 450 million cubic feet per day [**26**].

Similar concerns are being expressed with regard to the size of the offshore Atlantic undiscovered gas resource base. Although the offshore Atlantic is thought to have as much as 63 trillion cubic feet of ultimate resources,[5] no large discoveries have been made since the Deep Panuke field (1 trillion cubic feet) was discovered in 1999 [**27**]. The Deep Panuke is the only new gas field expected to go into operation by 2006 (at 400 million cubic feet per day) and only the second offshore gas field to go into production in East Canada (after Sable Island). Since 1999, exploration results have generally been disappointing, and a number of dry wells have been drilled. In August 2002, however, the deepwater gas discovery by EnCana and Marathon Oil revived hopes for more large finds. The lack of commercial gas discoveries in the offshore Atlantic caused Eastern Canadian gas reserves to decline in 2002 by an amount equal to the annual gas production of the Sable Offshore Energy Project, about 190 billion cubic feet. Given the concerns about depletion of conventional gas resources in both the WCSB and offshore Atlantic regions, Canadian producers are considering the commercial viability of both conventional Arctic gas resources and other unconventional gas resources, especially coalbed methane and gas hydrates.

In the Arctic region of the MacKenzie Delta-Beaufort Sea (MacKenzie), 9 trillion cubic feet of marketable natural gas reserves has sparked interest in the construction of a gas pipeline into Alberta [**28**]. Another 55 trillion cubic feet is expected to be discovered [**29**]. Given the perceived decline in WCSB conventional gas resources, producers have discussed the development of Canada's Arctic gas resources since 2001. One proposal called for about 1 billion cubic feet per day of MacKenzie gas to be transported by an Alaskan gas pipeline, which would have started on the Alaska North Slope, crossed the Beaufort Sea to MacKenzie, and then proceeded south to Alberta. The proposal was scuttled by the Alaska State Legislature, which mandated that an Alaska North Slope gas pipeline first go to Fairbanks and then proceed along the Alaska Highway before entering Alberta. Since then, the MacKenzie Delta pipeline has been envisioned as a standalone pipeline [**30**].

Given the uncertainty surrounding the construction of an Alaska gas pipeline and the expected growth in consumption of Canadian natural gas in both U.S. and Canadian markets, some developers are considering expanding the proposed capacity of the MacKenzie pipeline up to 1.9 billion cubic feet per day [**31**]. Part of the pipeline's capacity is expected to provide energy for Canadian tar sands production in Alberta, which requires about 600 cubic feet to produce each barrel of tar-sand oil [**32**]. Whether all the proposed tar sands projects will come to fruition is now under question because of the Canadian ratification of the Kyoto Treaty on December 10, 2002 [**33**].

Canadians are also considering unconventional gas resources as a supplement for conventional natural gas. The two principal unconventional gas resources being examined are coalbed methane and gas hydrates. Coalbed methane is attractive because the gas resources are estimated to be quite high, amounting to as much as 135 trillion cubic feet in Alberta alone [**34**]. The actual resource is still highly speculative, however, because there is currently no coalbed methane production in either Alberta or British Columbia, where the majority of Canada's coalbed methane resources are located. The current lack of coalbed methane production reflects both the low historic cost for developing WCSB conventional gas resources and unresolved issues about the ownership of mineral rights.

The other potential source of unconventional gas supply is natural gas hydrates, which consist of methane molecules locked in water crystals. The formation of gas hydrates occurs under low temperatures and/or high pressures. Gas hydrate deposits are found offshore in

[5]Composed of 18 trillion cubic feet in the Scotian Shelf and 45 trillion cubic feet in the Grand Banks/Labrador areas.

deepwater sediments and onshore in the Arctic permafrost [***35***]. Two test wells have been drilled in the MacKenzie Delta region of Canada. The second well, drilled in 2002, underwent a brief gas production test, which apparently gave encouraging results. Even if gas hydrate production is found to be both feasible and profitable, however, development of Canadian resources would require the construction of a gas pipeline from the Canadian Arctic to the southern gas markets.[6]

Mexico

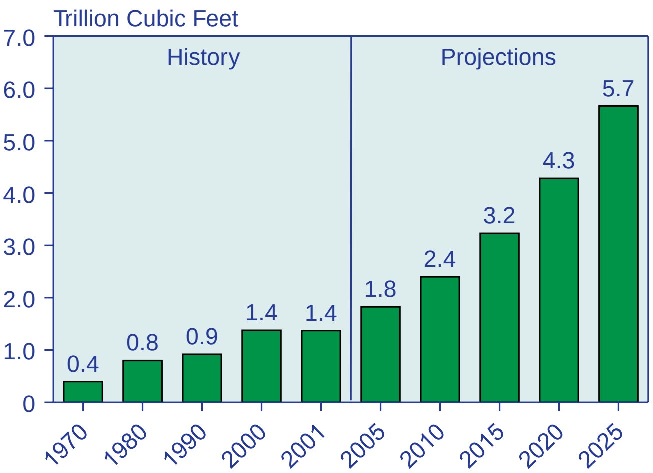
Natural gas consumption in Mexico has grown steadily over the past decade, from 0.9 trillion cubic feet in 1990 to 1.4 trillion cubic feet in 2001. For most of the decade, consumption has outpaced production, with the difference being supplied by imports from the United States. The Mexican government expects natural gas consumption to be double its 2000 levels by 2010. In the *IEO2003* reference case, strong growth is expected to continue throughout the forecast period, with consumption of natural gas projected to increase at an average annual rate of 6.1 percent per year between 2001 and 2025, reaching 5.7 trillion cubic feet in 2025 (Figure 48).

Much of the projected increase in Mexico's gas demand is expected to be for the industrial sector and for electricity generation. Residential and commercial consumption of natural gas is also expected to increase as a result of the 1995 privatization of the transmission and distribution sector that has brought natural gas distribution systems into numerous cities that before had either limited or no access to natural gas. While Mexico is currently satisfying approximately 10 percent of its demand with imports, the government anticipates that, even if production grows at an average annual rate of 9 percent, imports in 2010 will account for closer to 20 percent of total consumption.

The Mexican government's main concern about increasing imports is price, because domestically produced natural gas is significantly less expensive than imports. The availability of pipeline capacity for imports from the United States, at least in the near term, is not a major issue. There are currently 12 pipeline interconnects between Mexico and the United States, most capable of bidirectional flow. The total estimated capacity is approximately 2 billion cubic feet per day, giving an annual capacity well in excess of the 268 billion cubic feet exported to Mexico in 2002 [***36***]. Pipeline imports could increase more than fivefold before reaching capacity constraints. In addition to pipeline imports, LNG is expected to meet some of Mexico's growing demand. Several LNG receiving facilities have been proposed on both the eastern and western coasts. Although local opposition has hindered development of facilities in Baja California, it is expected that a suitable Baja location will eventually be agreed upon. Plans along the east coast are further advanced. The Mexican government has issued a tender to build a regasification facility by 2006 at Altimira, with proposals due the end of April 2003. Mexico's Federal Electricity Commission has indicated that it will commit to purchase 425 million cubic feet per day of LNG imports from the facility for 15 years.

Until recently, lack of investment in exploration and development by Petroleos Mexicanos (PEMEX), the state oil and gas company, kept new discoveries, and hence production, down. In light of Mexico's expected high growth in demand, more attention is now being focused on exploration and development. In September 1999, PEMEX proposed a strategic gas program to increase both reserves and production. Referred to as PEG, the program consists of 22 projects, all initiated in 2001, with an expected cumulative capital expenditure between 2001 and 2009 of $8.1 billion. In 2001 $1.6 billion was spent, funding the largest seismic and drilling activity in Mexico since the 1980s. Seven new fields were discovered, six offshore and one onshore, and 1.8 trillion cubic feet was added to reserves. The most promising of the new fields, the Lankahuasa, is located in shallow waters in the offshore Gulf of Mexico and may contain up to 1 trillion cubic feet of reserves. Another promising discovery is the Playuela area of the Veracruz basin, which has reactivated this mature gas-producing basin.

Figure 48. Natural Gas Consumption in Mexico, 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 (2003).

[6]The *IEO2003* projections for Canadian gas supplies do not include any contribution from gas hydrates.

PEMEX's goals for the next 5 to 10 years include exploration in new areas, particularly nonassociated basins[7] and the deepwater Gulf of Mexico[8]; reduction of finding and production costs; application of new technology in mature fields; strengthening the capabilities of technical personnel; and increasing foreign involvement. Two challenges that could slow the progress of the ambitious PEMEX plan are lack of autonomy in decisionmaking and the need to negotiate budgets with the government.

The PEMEX business plan is expected to increase production significantly, even without foreign involvement, but its efforts alone will not be sufficient to achieve the Fox Administration's goal of eliminating imports by 2010. Because it lacks the financial resources to develop the country's reserves fully on its own, the government feels that it is imperative to open the natural gas production sector to private investment. At present, private companies can provide services to PEMEX but are prohibited by the constitution from holding any share of ownership in any of Mexico's natural resources. A new contractual arrangement known as the Multiple Service Contract (MSC) has been developed by PEMEX to replace the current arrangement with contractors providing oil and gas related services. The MSC is considered to be a key element for future development. Although PEMEX will maintain strict control over exploration and production in accordance with the Mexican constitution, the new arrangement has been designed to open new opportunities and investment areas in the natural gas industry and to make participation more attractive to investors. It is hoped that the new MSC will attract sufficient foreign investment to supplement PEMEX's to the point that enough gas can be produced to satisfy demand by 2010. The initial emphasis will be on getting contracts in place for development efforts in the Burgos Basin[9] in northeastern Mexico, where PEMEX feels the largest production increase could be achieved.

The Fox Administration's immediate goal—to double production in the Burgos Basin from 1 to 2 billion cubic feet per day within the next 3 years—depends on the acceptance of the MSC. There is still resistance within Mexico on constitutional grounds, however, and lawyers continue to evaluate the issue. In addition, PEMEX labor unions have strongly opposed foreign involvement in the past and will most likely continue to do so. Although significant interest has been generated among investors, many remain skeptical as to its true benefits. Features that PEMEX feels will be attractive to contractors include PEMEX's commitment to produce at least 1 billion cubic feet per day from MSCs by 2007, its guarantee that all work under the contracts will be performed in areas with certified gas reserves, the length of the contracts (20 or so years, compared with the current 1 to 2 years), and unit pricing for work units performed that will reward efficiency regardless of production.

The primary disadvantage of the MSC for potential investors is that PEMEX will retain ownership of all resources and of all works performed. President Vicente Fox has had difficulty in his attempts to restructure Mexico's energy markets since he took office on December 1, 2000, because his party lacks a majority in both of the Mexican government's legislative bodies. Consequently, he has narrowed his immediate focus to one primary area, that of opening up exploration and development of nonassociated gas to private investment. PEMEX will initially offer eight blocks in the Burgos Basin for exploration and development through the MSC. The blocks contain proven reserves of 800 billion cubic feet and potential reserves of 3 to 4 trillion cubic feet. It is anticipated that the contracts will be awarded by September 2003 [***37***].

Although Mexico is making progress with efforts to open its upstream natural gas market, the lack of emphasis in the past has left the country unable to develop its resources fast enough to keep pace with the rapid growth in demand that is anticipated, at least in the near term. Mexico is thus expected to be a net importer of natural gas from the United States at least through 2015. If the government's goal of infrastructure development along with the development of additional sources of supply, such as LNG, is met, then after 2015 the country could become a net exporter. Mexico is expected to become a net exporter to the United States after 2019, and its net exports to the United States are projected to reach 0.7 trillion cubic feet per year by 2025 [***38***].

Western Europe

Natural gas remains the fastest growing fuel source in Western Europe, in spite of dwindling indigenous supplies. In the *IEO2003* reference case, Western Europe's natural gas consumption is projected to almost double over the forecast period, growing at an average annual rate of 2.4 percent, from 14.8 trillion cubic feet in 2001 to 25.9 trillion cubic feet by 2025 (Figure 49). Such growth would mean increased dependence on imports to satisfy requirements for natural gas. By one recent estimate, Western Europe's import dependence for natural gas is projected to reach 60 percent by 2020 [***39***]. With the exception of small quantities exported by France, Germany, and Norway to Eastern Europe, all Western European production is consumed in the region.

[7]Most of Mexico's reserves lie in the south and are associated with oil production. Because sufficient infrastructure to move the gas to major consuming centers in the north is lacking, a significant amount of natural gas is flared.

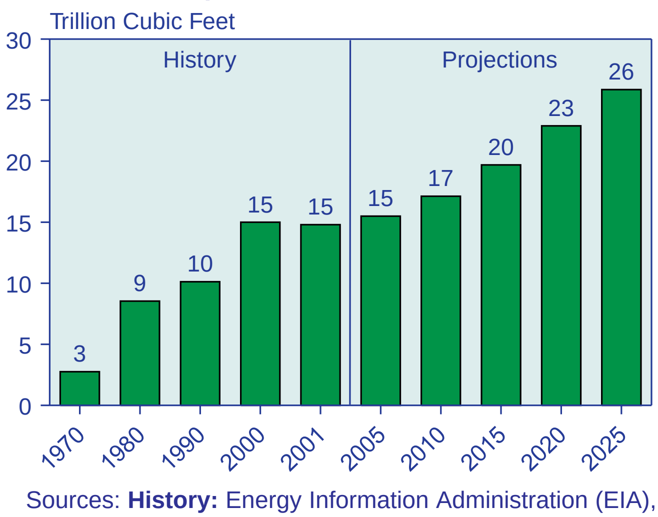
[8]Most offshore production is currently from very shallow wells.

[9]The Burgos Basin currently accounts for close to 25 percent of Mexico's production. In production since 1945, it is both the only major field in northern Mexico and the only major field producing nonassociated gas.

Most of the region's resources are concentrated in the United Kingdom, the Netherlands, and Norway. All three countries currently produce more than they consume and export the balance. Of the other Western European countries, only Denmark produced more than it consumed in 2001, exporting the balance to Germany and Sweden; and only Austria, Italy, and Germany produced more than 20 percent of what they consumed. France, the fifth largest natural gas consumer in Western Europe in 2001, produced less than 5 percent of what it consumed. Currently, the primary sources for imports of natural gas to Western Europe are Russia and Algeria for pipeline imports, as well as numerous sources, including Algeria, for LNG. France, Spain, and Italy are Europe's biggest importers of LNG, supported by exports from (in order of volume in 2001) Algeria, Nigeria, Qatar, Oman, Libya, Trinidad and Tobago, the United Arab Emirates, and others.

The United Kingdom is at present Western Europe's largest producer and second largest consumer of natural gas. For the past several years it has been a net exporter of natural gas, sending supplies to the Netherlands, Ireland, Germany, France, and Belgium in 2001 [***40***]. The United Kingdom is also Western Europe's oldest gas market, with many large, older gas fields that are or will soon be in decline. As a result, no significant growth in production is expected without new finds. With the *IEO2003* projecting gas consumption in the United Kingdom to grow from 3.3 trillion cubic feet in 2001 to 5.0 trillion cubic feet in 2025, other sources of natural gas will be needed.

Figure 49. Natural Gas Consumption in Western Europe, 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 (2003).

Centrica, a major UK energy supplier, already has entered into import agreements to start in 2005 with Statoil of Norway and Gasunie of the Netherlands. Arrangements have also been made with ExxonMobil for LNG from Qatar to begin flowing to the United Kingdom by 2007. Plans for new import pipelines are under consideration, with the Netherlands proposing a pipeline traversing the North Sea and Marathon and Statoil both proposing pipelines to bring gas from the North Sea (and potentially the large Norwegian Ormen Lange[10] field) to the United Kingdom. All three proposals would bring gas to Bacton, the delivery point for gas from Zeebruge, Belgium via the Interconnector pipeline, which is one of two currently existing pipelines used to import gas into the United Kingdom. The other is the Vesterland (previously Frigg) pipeline from Norway, Western Europe's second largest producer, which delivers gas to St. Fergus, Scotland. Plans have been announced to add compression that will almost triple the capacity of the Interconnector by 2005.

In addition to proposed international pipelines, the United Kingdom has several domestic pipelines that deliver gas from its own North Sea fields with spare capacity that could easily be linked to Norwegian offshore fields. Norway exports a significant amount of natural gas via pipeline and is also entering the LNG market. Europe's largest liquefaction plant is being built to process gas from the Snohvit and other fields in the Barents Sea 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 is expected to go into production by 2006 [***41***].

The largest supplier of natural gas imports to Western Europe is Russia, and those imports continue to grow. In the first 7 months of 2002, Western European imports of Russian gas increased by 5.4 percent over the same period in 2001 [***42***]. Russia has plans to increase its presence in Western European markets by building a pipeline that would bypass Ukraine and Poland (to avoid high transport fees and unauthorized diversion of gas) and initially transport gas from the Yamal Peninsula in Western Siberia to Finland, Sweden, and Denmark. The intention is to extend the pipeline subsequently to the Netherlands via Germany and then along the floor of the North Sea to the United Kingdom [***43***].

Natural gas will continue to flow to Western European markets through Ukraine, but Ukraine's aging pipeline system has deteriorated to the point that it is operating at only 50 percent of capacity. Steps are being taken to bolster Ukraine's transmission system. In early October 2002, the Russian and Ukrainian Prime Ministers took initial steps toward setting up an international consortium to manage and develop Ukraine's natural gas transmission system for a 30-year period. Several key

[10] Ormen Lange is the second largest natural gas field discovered to date in Norwegian waters.

issues, such as how shares in the venture should be distributed, remain to be resolved, but if the proposed upgrading of the system occurs, it will allow a significant increase in Russia's export capacity to Western Europe [**44**]. Western Europe also imports gas from other former Soviet Republics, notably, Turkmenistan, Kazakhstan, and Uzbekistan.

Another important source of natural gas supply for Western Europe is North Africa, and transport capacity between Europe and North Africa is being increased. North Africa (primarily Algeria) is Western Europe's second largest supplier, delivering supplies via pipeline to Italy, Spain, and Portugal and by LNG tanker to France, Spain, Italy, Belgium, Greece, and Portugal. Sonatrach, Algeria's national gas company, has an interest in a proposed LNG regasification terminal in Spain and is involved in a new venture with Gaz de France to market Algerian gas in Europe. A feasibility study has been completed for a pipeline to link Algeria with Spain, and construction is scheduled to begin in 2003. The pipeline is being constructed as a joint venture between Sonatrach and several leading European energy groups, including Cepsa, BP, Endesea, ENI, Gaz de France, and TotalFinaElf [**45**]. Algeria is increasing its exploration activities 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 [**46**].

Supplies of natural gas from Iran could also make their way to Western Europe. Iran has recently completed a pipeline link to Turkey, which it hopes is the first step toward providing supplies to Europe. The International Energy Agency, in its *World Energy Outlook 2002*, indicates that Iran, with its abundant gas supplies, is likely to become a major European gas supplier in the future [**47**]. Other options for moving Iranian gas to Europe are LNG by tanker and a pipeline through Armenia to Georgia and then on to Ukraine for ultimate delivery to Europe. The most expeditious solution will most likely be the completion and expansion of the pipeline project currently delivering Iranian gas to Turkey [**48**].

Turkey has also expressed considerable interest in entering the Western European natural gas market. The Turkish Energy and Natural Resources Minister, Zeki Cakan, has stated that preparations have been made to export natural gas to both Eastern and Western Europe. He indicated that Turkey would be signing an agreement to supply Greece with natural gas and was prepared to export gas not only to Greece but also to Austria, Hungary and Bosnia and Herzegovina [**49**]. The Austrian energy and chemicals group OMV and Hungarian oil, gas, and petrochemicals company MOL have agreed with the energy firms Botas (of Turkey), Bulgargaz (Bulgaria), and Transgaz (Romania) to undertake a 1.5-year feasibility study for a natural gas pipeline that would link Turkey with Austria via Bulgaria, Romania, and Hungary to satisfy growing demand in Eastern and Western Europe [**50**].

The European Union (EU) has set a major goal to create a single market for all aspects of trade and commerce by 2010. Important to the achievement of that goal is the liberalization of European energy markets. Virtually all European natural gas markets were founded as nationalized industries with limited, if any, participation by private companies [**51**]. The EU's legislation has played a significant role in the domestic energy policies of member countries, providing a framework for opening up both electricity markets and natural gas markets in member nations to competition.

The EU's Natural Gas Directive, passed in June 1998, required the opening of natural gas markets. It set deadlines for members (with the exception of emerging markets in Portugal and Greece) to have arrangements in place for third-party access to gas infrastructure, with target dates for individual customers set according to consumption levels. As a result of the Directive, markets in Germany and the United Kingdom were 100 percent open by 2000. Markets in Austria, France, Greece, and Portugal were less than 40 percent open, and all other EU member countries were between 40 and 99 percent open. By 2008, the European Commission projects that natural gas markets in Austria, Italy, the Netherlands, Spain, and Sweden will also be 100 percent open. The opening of gas markets is being accompanied by major changes, with nationalized gas companies being privatized, various components of the gas supply chain being bought and sold, and companies joining together to form trading alliances. These ongoing changes will facilitate cross-border trading, making a significant contribution toward meeting Europe's growing natural gas needs.

Industrialized Asia

The three countries of industrialized Asia—Japan, Australia, and New Zealand—saw relatively strong annual growth in natural gas use from 1990 to 2001—2.5 percent per year in Australia, 2.8 percent in New Zealand, and 4.0 percent in Japan. Over the projection period, the expansion of gas consumption in Japan is expected to slow considerably, increasing by a modest 1.0 percent per year between 2001 and 2025, whereas natural gas use in Australia and New Zealand combined is projected to grow by a robust 2.7 percent per year (Figure 50). Australia has only recently begun to exploit its vast natural gas resources for domestic use and in both Australia and New Zealand strong economic growth is expected to be accompanied by increasing natural gas consumption over the forecast period.

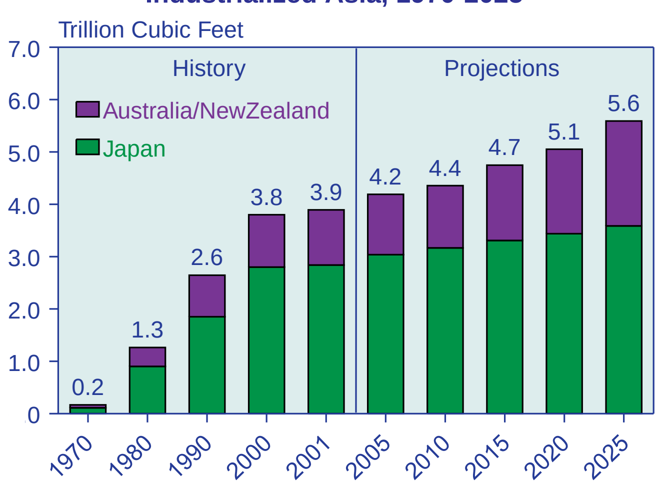
Japan

Japan is by far the largest importer of LNG in the world and, with few indigenous gas resources and limited options for pipeline imports, is expected to remain so for the foreseeable future. In 2001, Japan imported 2,615 billion cubic feet of LNG, accounting for more than one-half of the LNG traded worldwide [*52*]. In 2002, seven nuclear power plants operated by the Tokyo Electric Power Company (TEPCO) were shut down after the announcement by Japan's Nuclear and Industrial Safety Administration of suspicions that the utility had falsely reported the results of safety inspections on the reactors beginning in the mid-1980s; and by April 2003 operations had been suspended at all 17 of TEPCO's reactors, pending inspection [*53*]. Both TEPCO and the Chubu Electric Power Company—the latter with 3 nuclear reactors temporarily shut down for scheduled maintenance and another for unscheduled inspection—have been relying on natural gas (along with coal- and oil-fired generation) to meet high winter demand for electricity.

Australia

Australia's proven natural gas reserves are currently estimated at 90 trillion cubic feet, second in size only to Indonesia among the countries of the Asia/Pacific region. In spite of the country's vast resources, Australia has been fairly slow to advance the use of natural gas, which accounted for less than one-fifth of its total energy consumption in 2001. Natural gas is expected to gain market share of total energy consumption over the projection period as regulatory changes that have restructured the natural gas industry take hold and the pipeline infrastructure is expanded. The industrial sector currently is the largest consumer of natural gas in Australia, and increased use of natural gas for electricity generation is expected over the forecast horizon.

Figure 50. Natural Gas Consumption in Industrialized Asia, 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 (2003).

Although the Australian gas distribution network presently supplies some 3 million residential and 80,000 commercial customers, the pipeline system is fairly dispersed and fragmented and will have to be expanded to meet growing consumer demand for natural gas. In 2002, the country completed a 455-mile pipeline to Tasmania and started construction on a second hub, the so-called VicHub in Longford, Victoria [*54*]. There are currently plans to add some 5,000 miles of gas pipeline to the Australian system, including construction of a 2,000-mile pipeline to connect Australia's Queensland with Papua New Guinea.

Australia began exporting LNG in 1989 [*55*] and currently is the third largest LNG producer worldwide, after Indonesia and Malaysia. Australia plans to expand its Northwest Shelf Project by a fourth train,[11] adding 4.2 million metric tons of new capacity to the existing 8.0 million metric tons by 2004 [*56*]. The marketing company Australia Pty Ltd was able to secure a long-term contract to supply China's Guangdong regasification terminal with LNG beginning in 2005 when the terminal is scheduled for completion. Australia has also supplied substantial amounts of LNG to Japan and modest amounts on the spot market to the United States and South Korea.

New Zealand

In contrast to Australia, New Zealand has fairly modest natural gas resources. In 2003, the country's proven natural gas reserves stood at 3.1 trillion cubic feet. New Zealand's largest natural gas field, the Maui field in the Taranaki Basin, is now in decline, prompting many industry and government officials to speculate that without additional, large gas finds, New Zealand could exhaust its reserves within the next decade [*57*]. There is concern that too few resources are being invested in natural gas exploration, creating the potential for shortages in the mid-term.

Eastern Europe and the Former Soviet Union

As of January 1, 2003, the FSU held 36 percent of the world's natural gas reserves. In 2001 the FSU accounted for about 28 percent of the world's natural gas production, and 80 percent of the region's production was attributable to Russia. Russia's natural gas production in 2001 was second only to the United States, which produced 22.5 percent of the world's total compared with Russia's 22.0 percent. Growth in natural gas production and consumption among the EE/FSU countries was

[11] An LNG "train" is an independent unit for gas liquefaction. An LNG liquefaction plant comprises one or more LNG trains, and individual trains may vary in size. Significant capital costs are incurred in the construction a new LNG facility (known as a greenfield project), because infrastructure, such as ship terminals, must be built. With infrastructure already in place, it is more cost-effective to add a train to an existing LNG plant than to build a new facility.

mixed. Overall production within the FSU increased by 0.4 percent between 2000 and 2001, with decreases of 2.0 percent in Azerbaijan and 0.5 percent in Russia offset by increases of 9.1 percent in Turkmenistan, 2.3 percent in Ukraine, and 1.8 percent in Uzbekistan. While consumption dropped by 4.0 percent in Ukraine and 1.2 percent in Russia, a gain of 55.2 percent in Azerbaijan coupled with modest gains in other FSU countries overshadowed the losses, allowing the FSU to post an overall increase in consumption of 0.3 percent. This is the fourth consecutive year in which consumption in the FSU has increased, reflecting the region's continuing economic recovery.

Although unstable political and economic conditions in the early to mid-1990s led to significant declines in EE / FSU natural gas markets, conditions have improved considerably since then, and consumption continues to grow; however, the region's total consumption level of 24 trillion cubic feet in 2001 fell short of the 28 trillion cubic feet consumed in 1990. Restructuring of EE / FSU gas markets still is progressing, and the climate for foreign investment is improving. As a result, the *IEO2003* forecast projects robust growth, with consumption increasing at an average annual rate of 2.9 percent, to 46 trillion cubic feet in 2025 (Figure 51). Growth in Eastern Europe is expected to outpace growth in the FSU, with Eastern European consumption projected to grow at an average annual rate of 4.6 percent, compared with 2.6 percent for the FSU. One reason for the sizeable difference is that most of the countries in Eastern Europe have enjoyed sustained economic recovery since the early 1990s, giving them a head start over the former Soviet Republics, which have only recently begun to see sustained positive economic growth.

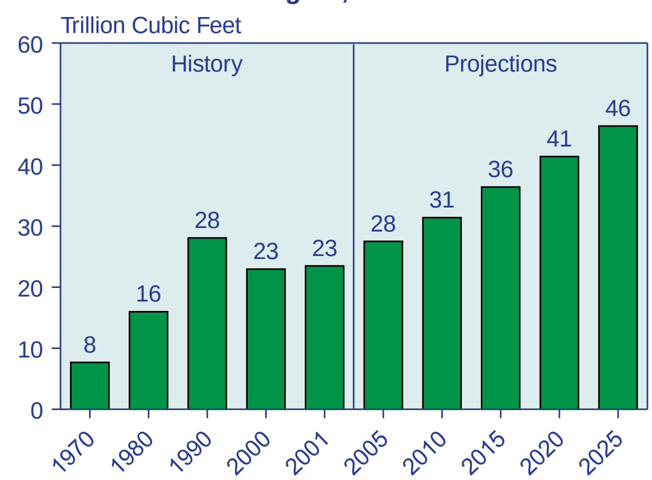
Russia dominated world trade movements in 2001, accounting for 31 percent of all natural gas pipeline exports and 23 percent of all international gas trade. The only other FSU country with any significant international trade was Turkmenistan, accounting for 1.0 percent of international pipeline movements with deliveries of 148 billion cubic feet to Iran, up sharply from 95 billion cubic feet in 2000. More than 60 percent of Russia's exports went to Western Europe. Out of a total of 2,740 billion cubic feet, 1,172 billion cubic feet went to Germany, 688 billion cubic feet to Italy, and 395 billion cubic feet to France, Russia's three main Western European markets. The remainder of Russia's exports to Western Europe went primarily to Austria, Finland, Greece, the Netherlands, and Switzerland [***58***]. Russia's exports to Western Europe in 2001 declined by 3.8 percent from 2000 levels, primarily because of lower deliveries to Italy. Italy increased imports from the Netherlands and began receiving supplies from Norway by way of the new Les Marches du Nord-Est pipeline in France.

Eastern Europe, Russia's second largest market, received 1,352 billion cubic feet and accounted for just over 30 percent of Russia's international natural gas trade. The other major recipient of Russian gas was Turkey, receiving 386 billion cubic feet or 8.6 percent of the total, up by 7.7 percent from 2000 levels [***59***]. Although Russia's exports to Eastern and Western Europe decreased between 2000 and 2001, they are now on the rise. The Interfax News Agency's October 10, 2002, *Petroleum Report* indicated that figures for the first 9 months of 2002 showed overall exports to all of Europe (including Turkey) increasing by 3.8 percent over the same period in 2001.

Notable in the EE / FSU has been the completion of major pipeline projects, the growth of international trade agreements, and progress on several infrastructure expansion proposals to facilitate international trade. Turkmenistan, Afghanistan, and Pakistan are once again discussing a $3.2 billion gas pipeline, known as the Trans-Afghanistan pipeline, to provide Turkmenistan supplies to the latter two countries. Originally planned in 1997, it was put on hold because of tensions between Afghanistan and Pakistan; however, the political climate has improved since the fall of the Taliban regime in Afghanistan and Pakistan's renunciation of the Taliban after the September 11, 2001, terrorist attacks against the United States [***60***].

Russia is exploring options to export natural gas to China, and the two countries are conducting a feasibility study that is expected to be completed by the end of June 2003. The gas would be supplied from Siberian gas fields in Irkutsk to provinces in Northeast China beginning in

Figure 51. Natural Gas Consumption in the EE/FSU 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 (2003).

2008 [61]. South Korea has also become a party to the endeavor. Although pipeline routes through Mongolia and Manchuria have been proposed, another possibility is the development of a liquefaction facility so that the gas could be transported as LNG to markets other than China. Preliminary plans for an LNG facility call for 7 million metric tons of LNG per year for 10 years beginning in 2008 or 2010 [62]; however, such ambitious plans are unlikely to reach fruition before 2015.

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 currently are on hold because of a slowdown in the Polish economy, which has resulted in a corresponding decrease in the need for natural gas, but Statoil may increase supplies to Poland via Germany until demand picks up enough to make the pipeline viable [63]. Poland has also contracted with Russia for supplies to be delivered through the Yamal pipeline. The original agreement is for close to 9 trillion cubic feet of gas to be delivered by 2020 under a take-or-pay agreement. While Poland still wants supplies from Russia, the government is anxious to renegotiate the amount. The economic slowdown the country is experiencing, coupled with overly optimistic demand projections that the previous government used when the contract was first negotiated, has led to a substantial overcommitment on Poland's part. Poland has proposed that the amount be reduced by 50 percent, whereas Russia is proposing 30 percent [64]. Meanwhile, because producing its own gas is significantly cheaper than importing it from Russia, the Polish government has made increasing gas production a priority, stating that it hopes to increase production by 50 percent in 2007 [65].

Europe is Russia's primary export market, but Turkey has long been felt to have strong potential as an outlet for Russian gas. Currently Russia's fastest growing export market, Turkey is in a position to overtake France as Russia's third largest foreign customer. Exports to Turkey for the first 9 months of 2002 were up by 14 percent from the same period in 2001 and are expected to grow further as a result of the recent opening of the Blue Stream pipeline in October 2002. The growth will not be as strong as originally anticipated, however, because Turkey's economic problems have reduced previously estimated demand requirements [66]. Finally a reality, the Blue Stream pipeline has been in the works since Russia and Turkey signed an agreement on December 15, 1997. The project faced competition from the rival Shah-Deniz pipeline, which was proposed to bring gas from Azerbaijan's Shah-Deniz gas field to Turkey. A major find for Azerbaijan, the Shah-Deniz field is estimated to contain more than 3 trillion cubic feet of reserves. Plans to develop the field and build the pipeline to Turkey have been delayed because of both significant cost increases and the uncertainty of Turkey's future demand for gas.

Russia is looking beyond supplying Turkey with natural gas via the Blue Stream pipeline, anticipating that Turkey will become a future transit route to Europe that will bypass Ukraine, Romania, and Bulgaria. Before the Blue Stream was opened, all Russian supplies entering Turkey transited those three countries. The Blue Stream is not Russia's only attempt to bypass Ukraine in delivering natural gas to Europe. Gazprom has completed the second line of the Yamal-Europe pipeline, which transports gas from Russia's Yamal Peninsula to Germany via Belarus and Poland [67]. The first Yamal-Europe line transits Belarus and Ukraine en route to Europe.

In the past, strained relations between Russia and Ukraine regarding the transport of Russian gas led Russia to seek alternate routes to Europe. 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. There is encouraging evidence that agreements have been reached and relations between the two countries are improving. According to Ukraine, Gazprom has agreed to transport about 4 trillion cubic feet of gas through Ukraine, paying part of the transit fee by providing the country with 900 billion cubic feet of gas and the rest in cash. Ukraine has also signed a contract with Russia for the transport of gas from Turkmenistan to Ukraine at a more favorable cost than that currently in effect and established an agreement that will allow Ukraine to export its own gas under Gazprom's export contracts [68]. In October 2002, Ukraine and Russia signed an agreement to set up an international consortium to refurbish and run Ukraine's aging pipeline system, which is badly in need of repair [69]. Initially consisting of Ukraine, Germany, and Russia, the consortium is open to all leading European companies.

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 the government and efforts at privatization and foreign involvement were just beginning to develop.

A positive trend has been the improving climate for foreign investment, which is vital to the full development of the region's gas markets. An example is the readiness of major European businesses to invest in Russia's key natural gas projects, such as the development of the Barents Sea Shtokmanovaski offshore gas fields, the Yamal-Europe pipeline, and the Northern European pipeline from Vyborg in Russia through Finland and under the Baltic Sea to Europe. The Northern European

Pipeline, expected to be completed by 2009, carries a price tag of $5.7 billion [**70**]. The combined cost of all three projects is estimated to be between $25 and $30 billion, and Russia does not have the means to complete them without foreign involvement.

Interest in the projects was affirmed after a Russia-EU roundtable conference on the natural gas industry in December 2002. According to Alexi Miller, Gazprom's CEO, Gazprom has already negotiated with Shell, BP, and Centrica in the United Kingdom, Fortum in Finland, and Ruhrgas, Wintershall, and BASF in Germany, all of which expressed interest in the construction of the Northern European pipeline. The pipeline would provide Russian gas initially to Finland, Sweden, and Denmark; later to the Netherlands via Germany; and finally to the United Kingdom through a segment crossing the floor of the North Sea [**71**]. Although issues surrounding market liberalization and contract structure for gas sales are items that still need to be addressed before any final agreements can be reached, this is a positive step forward for Russia [**72**].

In addition to possible foreign investments in its projects, Gazprom has its own ambitious investment program for 2003. The Russian giant's plans are to increase total investment by 50 percent over 2000 levels, with 8 percent of the total investment earmarked for boosting extraction and transportation of natural gas and to maintain existing pipelines [**73**]. Gazprom is also relinquishing a degree of its control over the Russian gas market. While it remains Russia's largest producer, independent gas companies are slowly increasing their share of the market. As an example, Russian gas company Nortgaz, a member of Soyugaz, Russia's union of independent gas producers, doubled its 2001 production in 2002 and plans to more than triple its 2002 output by 2005. Currently Gazprom accounts for close to 90 percent of Russia's production, but it has been projected that by 2020 independent gas companies will account for about 30 percent of production. Current obstacles faced by the independents include a lack of equal access to pipelines, need for more favorable tax consideration, and difficulty in achieving profitability. Given the current market structure, their profitability is less than 0.5 percent, whereas Gazprom's profitability is between 15 and 20 percent [**74**].

Developing Asia

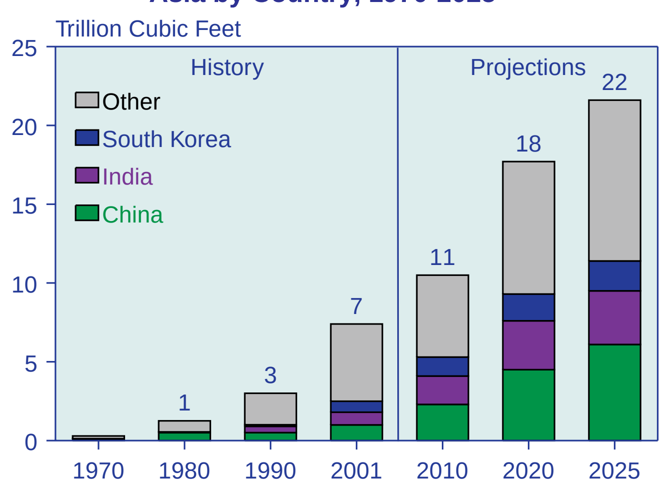
In the *IEO2003* reference case forecast, natural gas consumption is expected to expand strongly among the countries of developing Asia (Figure 52). Between 2001 and 2025, natural gas use is projected to increase by 4.5 percent per year in the region, about twice the rate projected for the countries of the industrialized world. Many countries in developing Asia are attempting to increase natural gas use, particularly for electricity generation in order to diversify electricity fuel mixes. Both China and India, two of the largest energy consumers in the region, have been making strong efforts to increase their natural gas supplies and to develop the infrastructure needed to bring gas to market. China and India together account for 55 percent of the expected regional increment in natural gas use, with projected average annual increases of 7.9 percent and 6.1 percent, respectively.

China

China's natural gas use currently accounts for a relatively small share of its total energy mix, only about 3 percent in 2001. In recent years, however, the Chinese government has made several moves toward increasing the penetration of natural gas in the country. Along with a number of aggressive moves in exploring its own natural gas resources, China has begun constructing LNG regasification terminals and several gas pipeline projects. The government has announced plans to ensure that Beijing's natural gas infrastructure is fully operational in time for it to host the 2008 Olympic summer games. In an effort to secure the Olympic games for Beijing, China committed $12 billion to reduce the pollution in the city, one facet of which will be to convert businesses from coal to natural gas [**75**]. Shanghai has announced that it will stop building coal-fired electric power plants and speed up the construction of natural-gas-fired plants [**76**].

In general, China's natural gas infrastructure is rudimentary. The largest gas pipeline distribution system is in the southwestern province of Sichuan, where some 5,400 miles of natural gas pipeline serves both industrial

Figure 52. 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 (2003).

chemical plants and residential consumers. The country has plans to increase gas supplies substantially and to expand the natural gas pipeline network in the near future. The most ambitious of the planned pipelines is the 2,600-mile West-to-East pipeline currently under construction, which will connect gas fields in China's sparsely populated west to urban markets in the east, initially running from the Tarim Basin in Xinjiang Province to Shanghai and subsequently connecting to Beijing through a 200-mile link.

Several major urban centers have made plans to expand and interconnect their natural gas pipeline distribution networks. In January 2002, PetroChina signed a contract to install 470 miles of pipe that will connect 11 cities in the central provinces of Hubei, Hunan, and Sichuan [*77*]. A 470-mile pipeline that was originally supposed to be constructed by the now bankrupt Enron Corporation to link Zhongxian in southwestern China's Chongqing Municipality to central Hubei Province will be completed by PetroChina, alone or with an alternative partner [*78*]. The $600 million project will deliver 106 billion cubic feet of natural gas each year to urban centers such as Wuhan, Changsha, and Zhuzhou. Another 300-mile pipeline to connect the Changqing gas field to the Inner Mongolian city of Hohhot is currently under construction and scheduled for completion before the end of 2003 [*79*]. The $100 million project is expected to transport some 34 billion cubic feet of natural gas per year to the city.

In addition to pipeline projects that will bring Chinese natural gas to market, PetroChina is negotiating with Russia for the import of about 700 billion cubic feet of natural gas per year from Russia's Kovytka field in 2008 through an extension of the West-to-East pipeline. Talks between China and Russia about constructing a natural gas pipeline from eastern Siberia to the Bohai Bay region of northeastern China also began in mid-2002 [*80*]. A feasibility study is currently underway and scheduled for completion by June 2003 [*81*].

There are also plans to introduce facilities for LNG in China. One LNG regasification facility is already under construction at Shenzhen in Guangdong Province, and there are plans to build other plants in Fujian and Shandong. In August 2002, state-owned China National Offshore Oil Corporation (CNOOC) secured supplies for the LNG plant from Australia's Northwest Shelf with Australian marketing company Australia LNG Pty [*82*]. The 25-year contract will begin in 2005, with the completion of the Guangdong import terminal, when an initial 3.0 million metric tons of LNG will begin to be delivered, rising to 5.0 million metric tons in 2008. In September 2002, BP-Pertamina and CNOOC signed an agreement for the latter to purchase 2.6 million metric tons of LNG from Indonesia's Tangguh field located in the province of Papua, beginning in 2007 [*83*].

India

In the *IEO2003* reference case projection, natural gas use in India advances strongly between 2001 and 2025, by 6.1 percent per year. Although gas use in the country is currently only 0.8 trillion cubic feet, India has plans to increase both imports and domestic production over the next few years. By 2025, natural gas consumption is projected to reach 3.4 trillion cubic feet.

Natural gas consumption is concentrated largely in India's industrial and electricity generation sectors. Most of the future growth in natural gas demand is expected to be for power generation, as a result of government incentives to increase gas-fired generating plants along the India's coastal areas where LNG will be received [*84*]. The Indian government has ambitious plans to expand the existing 2,000 miles of natural gas distribution pipelines. Projects already underway include a 380-mile pipeline to connect Visakhapatnam to Secunderabad in the state of Andra Pradesh and a 440-mile pipeline to connect Mangalore in Karnataka to Madurai in Tamil Nadu [*85*].

With the fast-paced growth projected for natural gas demand in India, it is likely that the country will have to import substantial amounts of natural gas to meet its needs in the future. At present, India's gas imports are solely in the form of liquefied petroleum gas (LPG). There have been several proposals in recent years to develop both pipeline and LNG imports. India's political relationships with neighboring Pakistan and Bangladesh have made it difficult to advance plans for pipelines to import gas through those two countries. There have been on-again, off-again talks between India and Oman, Iran, Bangladesh, and more recently Russia, but so far they have not resulted in any firm plans to develop a natural gas import pipeline.

As a result of the difficulties in establishing the infrastructure for importing natural gas via pipeline, much of the near-term growth in India's gas imports is likely to be in the form of LNG. The country's first LNG regasification terminal, Petronet's 5 million metric ton facility at Dahej in Gugarat, is scheduled to become operational by the end of 2003. There are currently eight LNG terminal projects under various stages of completion or under consideration in India.

The Indian government is also aggressively pursuing exploration for domestic natural gas. The country currently holds proven reserves of 26 trillion cubic feet, with most resources centered in the Bombay High offshore complex, Gujarat state (both on and offshore), the Brahmaputra valley in the northeast of the country, and Andra Pradesh. In January 2003, the discovery of the largest gas field to date in India, in the Krishna Godavari Basin, was announced [*86*]. Located off the eastern coast of India, the field is estimated to contain between 5 and 7 trillion cubic feet of natural gas. The latest find has led some analysts to question the extent to which India will need to rely on imports to meet its natural gas demand.

South Korea

South Korea has had some difficulty in securing sufficient LNG supplies in 2003. State-owned Korea Gas Corporation (Kogas) opted to delay renewing or signing any new LNG contract supply agreements in 2002 as it awaited a pending government decision about restructuring the country's natural gas markets [**87**]. This left the company much more dependent on spot markets for its supplies. According to Cambridge Energy Research Associates, the company required an estimated 40 additional LNG spot cargoes to meet the country's natural gas demand for what has become an unusually cold winter. Unfortunately, at the same time, Japanese utilities were forced to search for their own additional spot market purchases of LNG to fuel gas-fired electric power plants that were needed as a result of Japan's nuclear power plant inspection scandal, which had closed 17 nuclear power plants by April 2003.

The result has been a very tight LNG market for South Korea in early 2003. Korea is currently wholly dependent upon LNG imports for its natural gas supplies. The country is second only to Japan as an LNG importer worldwide. South Korea has contracts to purchase LNG from a wide range of countries, including Indonesia, Malaysia, and Qatar, with smaller amounts from Brunei and Oman [**88**]. In January 2003, Kogas signed a 7-year purchase agreement with Australia's North West Shelf LNG for 500,000 metric tons of LNG per year, starting in late 2003 [**89**]. Natural gas demand in South Korea has been increasing steadily since the country's recovery from the Asian economic crisis of 1998, and natural gas use is expected to increase by a robust 3.9 percent per year over the 2001-2025 forecast period.

Other Developing Asia

Indonesia and Malaysia are the largest natural gas producers in developing Asia. They account for a substantial amount of Asia's gas exports, both by way of pipeline (to Singapore) and in liquefied form (to Japan, South Korea, and Taiwan). In 2002, Brunei and Australia were the only other Asian gas producers that exported natural gas, both in LNG form.

Natural gas is becoming an increasingly important export commodity for Indonesia, which is now the world's largest LNG exporter, accounting for about one-fifth of the world export market in 2001 [**90**]. With an estimated 92.5 trillion cubic feet in estimated proven gas reserves, Indonesia possesses ample resources to support domestic markets and exports [**91**]. LNG is processed at the country's two liquefaction plants, PT Arun LNG at Lhokseumaw in Aceh and Bongtang LNG in East Kalimantan. A third plant is being developed by BP at Tangguh to supply China with LNG for its Fujian regasification terminal beginning in 2007 [**92**]. There have been problems associated with the Aceh facility; an insurgency group seeking independence for the island launched a series of attacks in 2001 that caused operator ExxonMobil to suspend operations for 3 months. The bombing of a night club frequented by western tourists in Bali in 2002 may also discourage foreign companies from investing in the Indonesian energy sector in the short term.

Indonesia has recognized the need to expand its domestic distribution systems for natural gas in order to fuel gas-fired electric power generation in a country where electricity demand is rapidly increasing. Between 1995 and 2000, net electricity consumption increased by a robust 10.3 percent per year in Indonesia, even with the economic slowdown that occurred during the 1997-1998 Asian financial crisis, ultimately bringing widespread social unrest that resulted in the ouster of President Suharto in May 1998 [**93**]. The state-owned gas distribution company, Perum Gas Negara (PGN), currently operates around 2,800 miles of natural gas pipeline throughout Indonesia, with another 1,100 miles of pipeline currently under construction [**94**]. PGN also has plans to build four new pipelines before 2007, adding 1,600 miles of new pipe in order to better integrate the national gas distribution system and make it easier to deliver gas supplies to consumers throughout the country.

In addition to the domestic expansion of its natural gas pipeline system, Indonesia is planning to increase its export capabilities. PGN has begun work on a 400-mile pipeline that would connect Sumatra with Singapore [**95**]. State-owned oil and gas company Pertamina expects to start delivering Sumatran natural gas to Singapore beginning in early 2005. Indonesia already provides Singapore with natural gas from its Natuna Sea field. There have also been discussions about constructing an ASEAN-wide natural gas pipeline system (which may begin on a fairly small scale), linking major gas producers Malaysia and Indonesia to Singapore [**96**]. So far, however, there are no concrete proposals in place to implement the scheme.

Like Indonesia, Malaysia is endowed with substantial proven natural gas reserves. As of January 1, 2003, Malaysia's reserves were estimated to be 75 trillion cubic feet [**97**]. The country produced 1.5 trillion cubic feet of gas in 2000, half of which it consumed for domestic markets and half for export. Also like Indonesia, Malaysia is a major exporter of LNG. In 2001, Malaysia alone accounted for 15 percent of the total world trade in LNG, exporting to Japan, South Korea, and Taiwan. There are currently some limited pipeline exports to Singapore as well.

In the eighth Malaysia National Plan, the government pledged to invest some $8.2 billion between 2001 and 2005 to develop the country's natural gas reserves to meet growing demand [98]. There are also efforts underway to enhance Malaysia's domestic and international gas distribution systems. A strong proponent of the proposed trans-ASEAN gas pipeline, Malaysia is working to establish a gas link with Thailand that would bring natural gas from the Malaysian-Thai Joint Development Area in the Gulf of Thailand into Malaysia for the first 5 years of operation and after that into Thailand as well [99]. The proposed pipeline has faced numerous delays because of concerns from environmental groups and local communities that would be affected. The project still faces several legal and regulatory challenges before construction can begin, but developers hope it can be completed by the end of 2005.

Malaysia currently consumes about one-half of its total natural gas production. More than three-quarters of the gas consumed in Malaysia is for electricity generation, but with industrial sector gas demand poised to increase strongly over the projection period, that share is expected to decline somewhat [100]. Malaysia is also one of the few countries in a position to diversify its electricity fuel mix by increasing generating fuels other than natural gas. The government is promoting the development of both coal-fired and hydroelectric capacity and is introducing incentives to increase the use of wind, solar, and mini-hydroelectricity. The electricity supplier Tenaga Nasional Berhad has also begun to use a blend of diesel fuel and palm oil at some electric power plants in order to help the government support Malaysia's palm oil industry, as well as to improve its fuel diversity. All these measures will lessen Malaysia's reliance on natural gas in the power sector.

Natural gas consumption in Thailand has tripled since 1990. Demand for natural gas increased even during the Asian economic crisis of 1997-1998, when demand for other fuels declined. The country has strongly expanded the use of gas in its electric power sector, which presently accounts for most of Thailand's demand, with the rest consumed in the industrial sector [101].

Proven natural gas reserves have grown steadily in Thailand with aggressive investment in the gas sector. In 1990, Thailand reported gas reserves of 6.9 trillion cubic feet; as of January 1, 2003, reserves had grown to 13.3 trillion cubic feet [102]. As a result, the country can currently meet most of its demand with domestic resources, but it is already securing imports of natural gas to meet the rapidly expanding market. Thailand imports a modest amount of natural gas from Myanmar through the Yadana-Ratchaburi pipeline, about 55 billion cubic feet of the 192 billion cubic feet originally contracted for by the state-owned Petroleum Authority of Thailand [103]. The company was forced to renegotiate the supply contract when the Thai currency collapsed in 2000, delaying the commissioning of the Ratchaburi gas-fired power plant.

Taiwan is another developing Asian country that has seen strong growth in natural gas consumption over the past decade, from 80 billion cubic feet in 1990 to 234 billion cubic feet in 2001. Much of the increment in natural gas demand has been to fuel electricity generation. The government has encouraged the development of LNG-fired power plants, and as a result the power sector now accounts for nearly three-fourths of total natural gas consumption in Taiwan.

With fairly modest natural gas reserves, estimated as 2.7 trillion cubic feet in 2003, Taiwan has been importing LNG since 1990 in order to meet demand [104]. LNG supplies are currently provided by long-term contract agreements with Indonesia and Malaysia. There are also plans by Tuntex Gas Corporation to procure supplies from Australia's Northwest Shelf Gas Project to supply its new regasification terminal in Taoyuan County [105]. Another potential source of LNG supplies for Taiwan may come from Russia's Sakhalin-2 project. Royal Dutch / Shell announced in 2003 that it was hoping to provide state-owned Taiwan Power with 1.7 million metric tons of LNG per year for a 25-year period beginning in 2008, pending construction of an LNG receiving terminal that is part of the tender [106]. Indonesia's Pertamina is competing with Royal Dutch / Shell for the contract.

Middle East

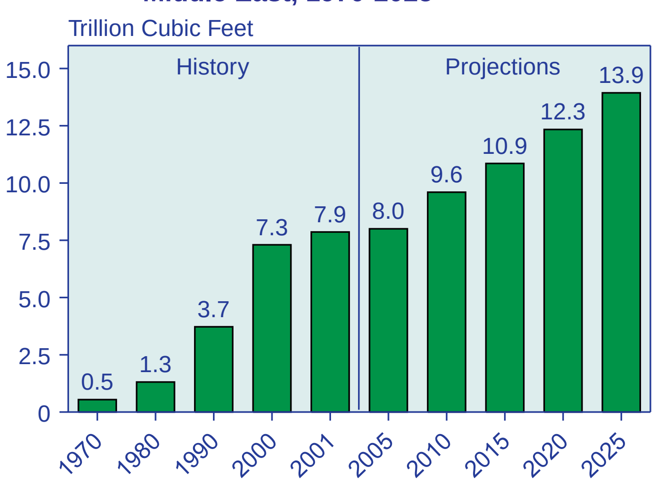
Natural gas consumption in the Middle East rose sharply in the 1990s, from 3.7 trillion cubic feet in 1990 to 7.9 trillion cubic feet in 2001 (Figure 53), and is expected to increase to 13.9 trillion cubic feet in 2025, at an annual average growth rate of 2.4 percent. Oil-exporting countries in the Middle East are seeking to expand natural gas use domestically so that as much oil as possible can be exported. Saudi Arabia, for one, has been trying to spur natural gas development for the past several years through its strategic gas initiative (see box on page 66).

Middle East countries are also planning to expand natural gas exports from the region. Although natural gas reserves in the Middle East are slightly higher than in the EE / FSU (see Figure 44), gas production lags far behind that of the EE / FSU region. In 2001, gas production in the Middle East totaled 8.3 trillion cubic feet, less than one-third of EE / FSU production. In contrast to the FSU, the Middle East has few pipelines. Nearly all natural gas exports from the Middle East are in the form of LNG. Countries in the Middle East are planning to increase LNG exports and also are exploring several pipeline options to increase export capability.

Turkey recently announced plans for a pipeline connection to Greece. Although the current proposal is modest, at 0.02 trillion cubic feet per year initially, it represents a first step for pipeline natural gas from the Middle East to reach the European pipeline network. The pipeline's overall capacity may be much higher, which would allow for additional throughput should plans advance for further connections to Europe via Italy or the Balkans [***107***]. Turkey's state-owned gas company, Botas, has also signed a separate agreement with the national gas companies of Bulgaria, Romania, Hungary, and Austria for a feasibility study on a gas pipeline that could bring Caspian or Iranian gas through Turkey [***108***].

Turkey is eager to develop re-export options for natural gas, having signed several contracts for natural gas imports only to see demand growth fail to keep pace with the contracted import volumes. Turkey recently negotiated a more flexible delivery schedule with Iran. Shipments will start at 0.07 trillion cubic feet in 2003 and rise by 0.04 trillion cubic feet per year to a plateau of 0.4 trillion cubic feet per year around 2010. The original schedule called for 0.1 trillion cubic feet per year in 2002 increasing to 0.4 trillion cubic feet per year by 2007. Russia's Gazprom has also agreed to reduce natural gas imports via the Blue Stream pipeline from 0.1 trillion cubic feet to 0.07 trillion cubic feet in 2003. Turkey is also scheduled to begin importing natural gas from Azerbaijan in 2006 under an agreement that calls for 0.07 trillion cubic feet per year initially, rising to 0.2 trillion cubic feet per year in 2009. The natural gas pipeline is to be constructed jointly and in the same corridor as the Baku-Tbilisi-Ceyhan (BTC) oil export pipeline [***109***].

Figure 53. 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 (2003).

Iran has the second highest natural gas reserves in the world behind Russia but did not begin exporting natural gas until 2001. Exports were cut off for several months in 2002, when Turkey complained about poor gas quality. Flows were restarted after negotiations reduced the delivery schedule as noted above. Iran is not only interested in expanding natural gas exports through Turkey to Eastern and Western Europe but has also discussed a pipeline to India. The pipeline could be built overland but would have to transverse Pakistan, which is very difficult politically. An undersea pipeline could avoid crossing Pakistan, but it would have to be built at depths of up to 11,500 feet, much deeper than the 7,000-feet depths reached by the Blue Stream line across the Black Sea [***110***].

In addition to pipeline projects, Iran is also planning to construct LNG facilities for exporting natural gas as part of its massive South Pars development. Iran's South Pars Oil and Gas Company is seeking bids for phases 11 and 12, which involve LNG exports from a proposed 8 million metric ton plant at Assaluyeh on the Persian Gulf. South Pars development has experienced some delays, however. Phase 1, involving natural gas and condensate production, is expected to come on stream around the end of 2003. Phases 2 and 3 started producing 0.4 trillion cubic feet of natural gas per year in March 2002. Phases 4 and 5 are stated to be back on track with some 28 percent progress [***111***]. Iran is aiming to supply India with LNG but will have to compete with several other producers in what is currently a buyer's market.

Qatar has been aggressively expanding its LNG facilities. Qatar has one of the largest gas fields in the world, the North Field, situated near Iran's South Pars field, and is aiming to triple its LNG capacity to 45 million metric tons per year by 2010. Qatar has long-term contracts with buyers in Spain, Japan, and South Korea, and agreements are in place for future deliveries to India, Italy, and the United Kingdom. Qatar has also sold spot cargoes to the United States. In addition, Qatar has plans to build gas-to-liquids plants and is expected to provide the natural gas for the first long-distance pipeline project in the Gulf area, the Dolphin project [***112***]. Dolphin Energy is waiting to sign a crucial long-term sales contract with the emirate of Dubai, which is expected to cover about one-half of the initial demand. The project is expected to pump at least 0.7 trillion cubic feet per year of Qatari gas to the United Arab Emirates [***113***].

Natural gas requirements have been outstripping production in the United Arab Emirates, which has given impetus to the Dolphin project. The vast majority of Abu Dhabi's gas reserves are associated and hence constrained by oil production. In addition, rising oil field reinjection requirements and a surge in power demand is pushing up the demand for natural gas. Dubai has also

The Saudi Gas Initiative

In the late 1990s, the government of Saudi Arabia was facing budget deficits and declining revenues from oil sales, the result of a combination of relatively low oil prices and high domestic unemployment rates. The government also recognized the need to increase electricity supplies in Saudi Arabia's rapidly growing residential and industrial sectors. By one estimate, Saudi Arabia will need at least $117 billion of investment in the electricity sector alone to meet demand in the next 20 years.[a] In 1998, the Saudi crown prince held informal discussions with several international oil companies about possible investment in the kingdom of Saudi Arabia. The attending companies were invited to submit proposals for exploration and development projects, primarily in the natural gas sector, as part of a "strategic gas initiative."

The Saudi Gas Initiative (SGI) has attracted considerable interest. Indeed, it amounts to the largest integrated gas development plan anywhere in the world. Saudi government advocates of opening the upstream sector to partnerships with foreign investors believe that the SGI will lead international oil companies to invest $25 billion in the near term and possibly further direct investment of $50 billion or more over the next 25 years. Further, they estimate that every dollar invested will generate $5 to $8 of investment in other sectors of the Saudi economy,[b] and that every billion dollars of investment by foreign oil companies will create 15,000 new jobs. The companies involved in SGI apparently do not believe that the projects proposed will achieve those goals,[c] arguing that natural gas and oil development are capital-intensive, not labor-intensive ventures and so cannot be used to solve Saudi Arabia's unemployment problem.

Although Saudi Arabia holds the fourth largest reserves of natural gas in the world, at 224 trillion cubic feet (of which 88 trillion cubic feet is nonassociated), the country has been slow to develop its natural gas resources. Saudi Arabia's current natural gas production is around 5.3 billion cubic feet per day.[d] The government has estimated that domestic consumption could increase by 12 to 14 billion cubic feet per day over the next 20 years or so, assuming that necessary investment will be made to convert existing oil-powered utilities to run on cheaper natural gas and to meet future demand for new capacity with more efficient gas-fired technologies.

The decision to open upstream natural gas development to foreign companies, as proposed in the SGI, has not been universally popular in Saudi Arabia and is particularly unpopular with the state-owned Saudi Aramco, which for the past 30 years has held a monopoly on the development of hydrocarbons in Saudi Arabia. Saudi Aramco believes it has proved its technical and managerial capabilities to explore and develop its natural gas reserves without foreign intervention. In 2002, for example, the company successfully developed the Haradh and Hawiyah gas projects, including the world's largest plant for processing nonassociated natural gas, as part of the Master Gas System (which predated the SGI).

From the beginning, the companies that were invited in 1998 to participate in the SGI had some difficulty obtaining the detailed information they needed to draw up proposals. In 2000, in an effort to speed up the process, the Saudi government created a new body, the Supreme Council for Petroleum and Mineral Affairs (SCPMA), to review SGI proposals and increase cooperation between the various Saudi ministries involved. The SCPMA was also given direct control over Saudi Aramco, an important aspect of the new body's function.

The SCPMA has indicated a preference for integrated natural gas projects that cover upstream nonassociated gas exploration and development, gas processing and transportation, and ethane and natural gas liquid extraction and fractionation facilities, as well as downstream power, water desalination, and petrochemical plants.[e] SCPMA has also stated clearly that Saudi Aramco will play an active role as a partner in any deal signed with foreign countries participating in the SGI. Other Saudi government bodies, such as the Electricity Authority, will also be involved, as will private Saudi companies either directly or through related services.

The SGI consists of three core ventures (see map on following page):

(continued on page 67)

[a]"Energy Sector Analysis: Saudi Arabia Oil and Gas," *World Markets Analysis OnLine*, web site www.worldmarketsanalysis.com (February 24, 2003).

[b]D. Sabbagh, "Saudi Foreign Minister Sees $50B Invest in Saudi Gas by 2025," *Dow Jones Newswires Release* (June 3, 2001).

[c]D.B. Ottaway and R.G. Kaiser, "After Sept. 11, Severe Tests Loom for Relationship," *The Washington Post* (February 12, 2002), p. A01.

[d]"Gas Assumes Prominent Saudi Energy Role," *World Gas Intelligence*, Vol. 13, No. 32 (August 7, 2002).

[e]"Saudi Arabia and Eight IOCs Sign Gas Initiative Preparatory Agreements," *Middle East Economic Survey*, Vol. 44, No. 24 (June 11, 2001), p. A9.

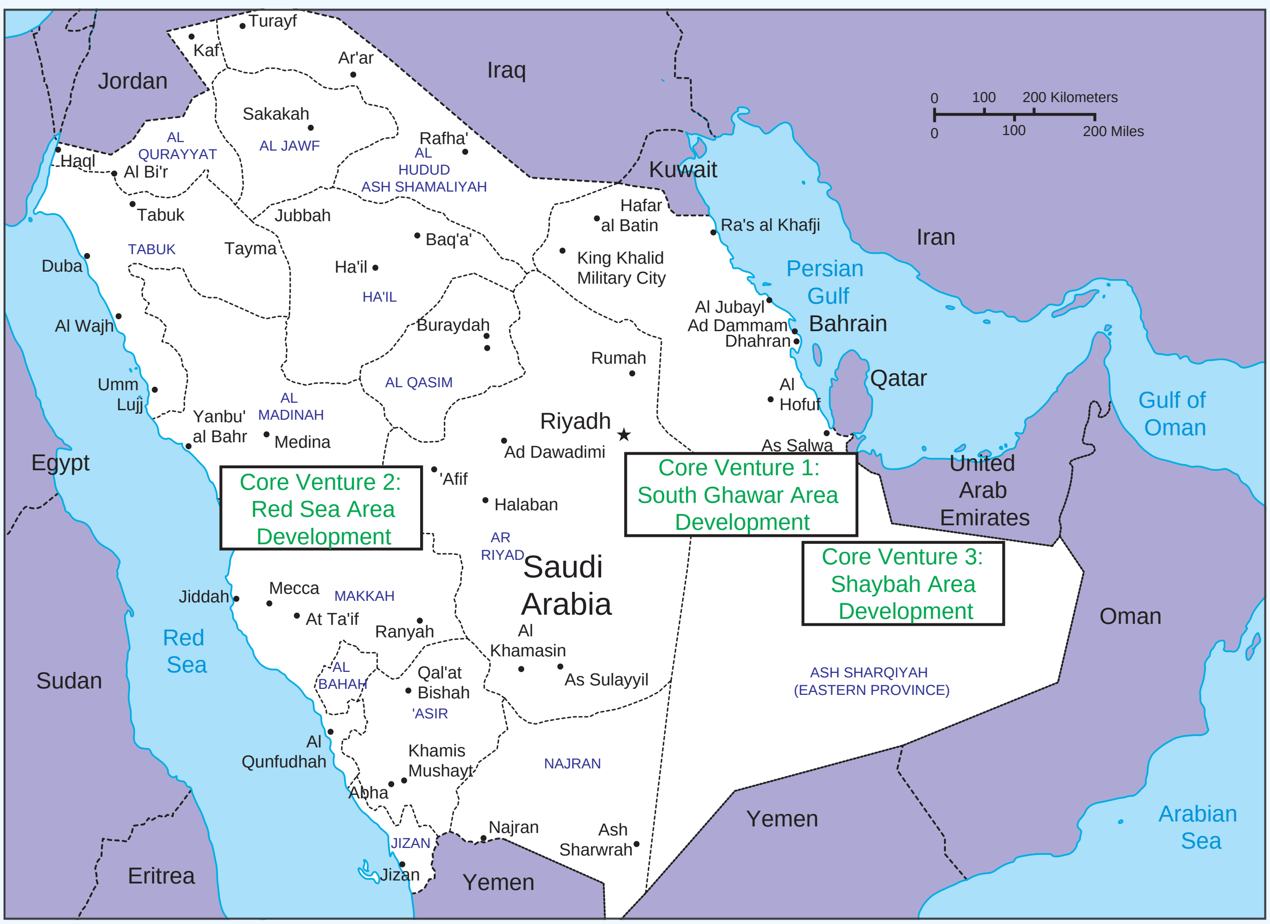
The Saudi Gas Initiative (Continued)

- Core Venture 1, the South Ghawar Area Development, is located in the eastern part of the kingdom, near the Persian Gulf. Natural gas would be produced from the southern part of the Ghawar oil field (the largest oil field in the world), in the Haradh and Hawiyah areas. Estimated gas reserves on offer are about 21 trillion cubic feet.[f] This venture also involves significant downstream elements, including two 2,000-megawatt power stations and desalination plants at Jubail and Yanbu that can produce 300 million gallons of desalinated water a day, and two petrochemical plants, one at Jubail fueled with ethane and a second at Yanbu fueled with mixed feedstocks, with a total capacity of 2 million metric tons of petrochemical production per year. The expected cost of Core Venture 1 is about $15 billion.

- Core Venture 2, the Red Sea Area Development, involves development of the Barqan, Umm Luj, Al Wajh gas fields in the northern Red Sea area, some of which were discovered in the late 1960s but have never been developed. With fewer proven gas reserves than Core Venture 1, the project will involve the development of pipelines to Tabuk and Yanbu, as well as construction of one power and one desalination plant. The estimated cost of Core Venture 2 is about $5 billion.

- Core Venture 3, the Shaybah Area Development, involves the development of the Kidan sour gas field near Saudi Arabia's eastern border with the United Arab Emirates, in addition to the installation of treatment and transport facilities for associated gas extracted from the Shaybah oil field, with potential reserves of 10 trillion cubic feet of gas and a production capacity of 600 million cubic feet per day. It includes the construction of a pipeline and petrochemical plant, a 1,100-megawatt power plant, and a desalination plant that can produce 75 million gallons of desalinated water a day, all to be located on the Persian Gulf coast. The estimated cost of Core Venture 3 is about $5 billion.

In January 2001, the SCPMA narrowed the list of potential SGI participants to eight. The companies *(continued on page 68)*



[f]"Saudi Gas Opening Not Closed Yet," *World Gas Intelligence*, Vol. 13, No. 38 (September 18, 2002), p. 1.

The Saudi Gas Initiative (Continued)

were grouped into three consortia, and a timetable was set to move forward. Later in January, Saudi Aramco's data rooms in Dhahran were opened to the short-listed firms. In May 2001 the composition and leadership of the consortia for the three core ventures was announced:

- Core Venture 1: ExxonMobil (lead with 35 percent), Shell (25 percent), BP Amoco (25 percent), Phillips (15 percent)
- Core Venture 2: ExxonMobil (lead with 60 percent), Occidental and Enron[g] (40 percent split between the two)
- Core Venture 3: Shell (lead with 40 percent), TotalFinaElf (30 percent), Conoco (30 percent).

The two leading companies in the three core ventures, ExxonMobil and Shell, are familiar with the local market conditions in Saudi Arabia as a result of their long-standing downstream joint venture projects dating back to the mid-1980s.

In June 2001—in the rare presence of the ailing Saudi king and the country's crown prince and other key officials—BP Amoco, Shell, ExxonMobil, Phillips, TotalFinaElf, Marathon, Occidental, and Conoco signed memoranda of understanding (MOUs) for the first foreign investment deals in the kingdom since Saudi Arabia nationalized its oil and gas sector in 1976.

Negotiations over details of the SGI have been slow and contentious since the signing of the MOUs in 2001. The Saudis were unable to reach an agreement with the foreign oil companies on a range of important issues. Final deadlines have come and gone with no agreement in the foreseeable future, leading to speculation that all three of the core venture projects ultimately may have to be re-tendered.

The issues of contention have ranged from determining tax terms and access to upstream gas reserves to ownership of the gas liquid, the guaranteed rate of return on investment, and tariffs on water and electricity. In their submissions, the international companies had assumed that a 30-percent tax rate would apply under Saudi Arabia's new laws on foreign investment; however, Saudi Aramco, supported by the tax authorities, sees gas development as subject to petroleum tax laws dating back to the mid-1970s, implying a 20-percent royalty before cost recovery and an 85-percent tax on the remaining output.[h]

The leading companies in the three core ventures stated that they had been led to believe that they would be given direct access to some 74 trillion cubic feet of nonassociated natural gas, whereas in fact the data submitted by Saudi Aramco showed the gas reserves to be far smaller than initially believed.[i] The downstream aspects of the core ventures would become less profitable if insufficient access to gas reserves drove up the cost of feedstocks bought from Saudi Aramco. The Saudis have indicated that extra acreage would be made available if there were insufficient volumes of gas in the areas assigned to the core ventures. On the liquid ownership issue, the Saudis are adamant that any oil or gas liquid developed from the scheme must be transferred to Saudi Aramco control.

Determining the guaranteed rate of return on capital has been among the stickiest issues in the negotiations. The foreign oil companies were seeking 18 to 20 percent as a guaranteed rate of return on their investments. The Saudis initially offered 10 to 12 percent, as is the norm for similar projects in the Persian Gulf region and in Europe,[j] but have recently revised the offer to a guaranteed rate of return between 14.5 and 15.5 percent for the three core ventures. They have also presented figures for the maximum prices per gallon of water and per kilowatthour of electricity to be produced in the proposed SGI water and power projects.[k] The new figures seem to be close to those desired by the participating foreign companies.

The Saudi government has suggested that it might also reduce the foreign companies' commitment to power and water projects, as they had been demanding, because there is an urgent need to press ahead with some of those projects. The Saudi government has been approached by a number of companies—particularly in the power and water sectors—offering their services at a lower rate of return and willing to team up with Saudi private investors, as was done by the first independent power producer in Saudi Arabia, a joint venture between a Saudi private investor (Al Zamil Industrial Group) and a foreign service company (CMS Energy) that was approved 2 years ago.[l]

[g]Enron, originally named as part of Core Venture 2, pulled out with no explanation and gave up its stake. Marathon was selected to replace Enron.

[h]"Motors Still Idling at Saudi Starting Line," *Petroleum Intelligence Weekly* (January 8, 2001), p. 1.

[i]"Saudi $25bn Gas Scheme Seen Teetering on Brink," *Platts: International Gas Report* (September 13, 2002), p. 1.

[j]"Saudi Arabia, IOCs in Gas Initiative Continue Work on Response to Ministerial Committee," *Middle East Economic Survey* (October 7, 2002).

[k]"UK Daily Energy News," *World Markets Analysis OnLine*, web site www.worldmarketsanalysis.com (October 1, 2002).

[l]Personal communication with Dr. Abdulrahman Al Zamil, Member of the Shoura Council and Chairman of Al Zamil Industrial Group, December 2002.

been receiving about 0.2 trillion cubic feet of natural gas per year from Abu Dhabi since 2000 to meet soaring power demand, a figure that is expected to grow. The project is aiming for 2006 for the first gas deliveries [*114*].

Africa

Natural gas consumption in Africa is projected to increase from 2.3 trillion cubic feet in 2001 to 5.3 trillion cubic feet in 2025 (Figure 54), at an average annual growth rate of 3.6 percent. Africa is a major exporter of natural gas. In 2001, Africa accounted for about 12 percent of the natural gas traded in the world. More than 85 percent of Africa's gas exports went to Western Europe. Natural gas exports from Africa are expected to increase through the forecast period, with Western Europe continuing to be the main recipient. Several pipeline and LNG projects are aimed at supplying the rising demand for natural gas in Europe.

Algeria is the second largest LNG producer in the world and also has significant pipeline exports. Algeria is hoping to add a new 4 million metric ton LNG train as part of the development of its Gassi Touil project, but the inability to pass a new hydrocarbons law, a dispute with European Union competition authorities over resale restrictions, and stiff competition from a growing list of LNG suppliers has slowed the process [*115*]. Algeria has expressed interest in expanding sales of LNG to the United States, which amounted to 0.06 trillion cubic feet in 2001, as a means of diversifying its customer base. Algerian Minister of Energy Chakib Khelil expressed concern, however, that a U.S. regulatory requirement for third-party access to any new receiving terminals may impede construction of new import terminals [*116*].

In 2001, Algeria exported 0.8 trillion cubic feet of natural gas via the Transmed (Enrico Mattei) pipeline through Tunisia to Italy. Sonatrach, the Algerian state-owned company, plans to boost the capacity of the line to 1.1 trillion cubic feet per year [*117*]. Algeria and Italy also agreed in late 2002 to explore the feasibility of another pipeline connection through Sardinia and Corsica. The new pipeline is expected to add export capability of 0.3 to 0.4 trillion cubic feet per year and would probably take 4 to 5 years to complete [*118*]. In addition, a feasibility study was done on a direct line from Algeria to Spain. Each of the seven European partners in the Medgaz pipeline project is understood to have signed or be close to signing a letter of intent to purchase 0.04 trillion cubic feet per year from the pipeline. Initial capacity is planned at 0.3 trillion cubic feet per year, with the possibility of increasing it to 0.6 trillion cubic feet per year [*119*]. Compressors are being added to the existing pipeline through Morocco to raise capacity to 0.5 trillion cubic feet per year by 2004, from 0.3 trillion cubic feet per year in 2002 [*120*].

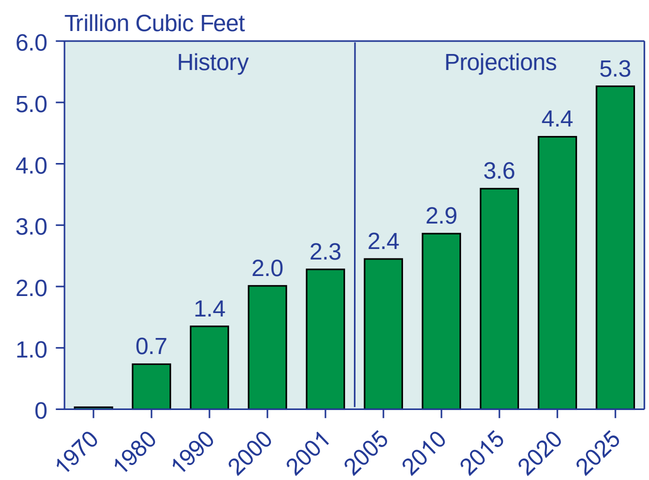
Egyptian LNG (ELNG) is moving ahead with plans to develop several trains at Idku. The entire output of the first train has been sold to Gaz de France under a 20-year agreement. The first train is already under construction, and production is expected to begin in the third quarter of 2005. The site can accommodate up to five trains, and an innovative commercial structure allows third parties to invest in future LNG production trains at the site. A second train is in the planning stages [*121*].

Spanish utility Union Fenosa hopes to start deliveries from its 5.0 million metric tons per year LNG train at Damietta, Egypt, in 2004, just a few months before the first output from the LNG facilities at Idku. Adequate gas supply has been a concern, but a discovery by Italy's ENI in late December 2002 may help to alleviate those concerns. A preliminary appraisal of the Tennin reserves came in at 0.5 to 1.1 trillion cubic feet. ENI recently purchased 50 percent of the gas business of Union Fenosa [*122*].

Libya is planning to expand its export capability by building a pipeline from Melitah on the Libyan coast to Gela in Sicily. With a capacity of 0.3 trillion cubic feet, the pipeline is part of the development of the onshore and offshore Wafa fields. It includes an offshore platform, gathering networks, and a gas treatment plant. The first gas is set to flow in 2005 [*123*].

Nigeria's natural gas reserves rank ninth in the world, but in the past more than one-half of its production has been flared due to lack of infrastructure. About 25 different gas projects are currently underway in Nigeria.

Figure 54. 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 (2003).

Some of the projects aim to reinject the gas, but others intend to channel supplies to Nigeria's expanding LNG facilities. The current deadline to end flaring is 2008, and Nigerian president Obasanjo has indicated a desire to move the deadline forward to 2004 [**124**].

Nigeria began exporting LNG from its third train on December 18, 2002, and signed a $1.06 billion loan on December 19 that will provide some of the funding for the fourth and fifth trains. Spain's Gas Natural (GN) and Portugal's Transgas have contracted for the supply from the third train [**125**]. Trains 4 and 5 are targeted for completion at the end of 2005. Nigeria LNG has four sales agreements and two memoranda of understanding covering the output from trains 4 and 5, all with European companies. Feedstock gas for the new trains is expected to be 100 percent associated gas, with nonassociated gas as a backup. The first two trains run up to 40 percent associated gas. A final investment decision on train 6 is expected in September 2003 [**126**].

Nigeria is also planning an export pipeline into Ghana, Togo, and Benin. The presidents of the four countries involved are expected to sign an intergovernmental treaty providing a common legal framework for the line, followed by the establishment of the West African Pipeline Company (Wapco). The project developers hope to begin pumping gas in 2005, with initial flow rates of about 0.07 trillion cubic feet per year [**127**]. Also under consideration is a pipeline north from Nigeria to supply natural gas to Niger and Mali, which could eventually be linked to the pipeline network in North Africa and provide pipeline gas to Europe [**128**].

Central and South America

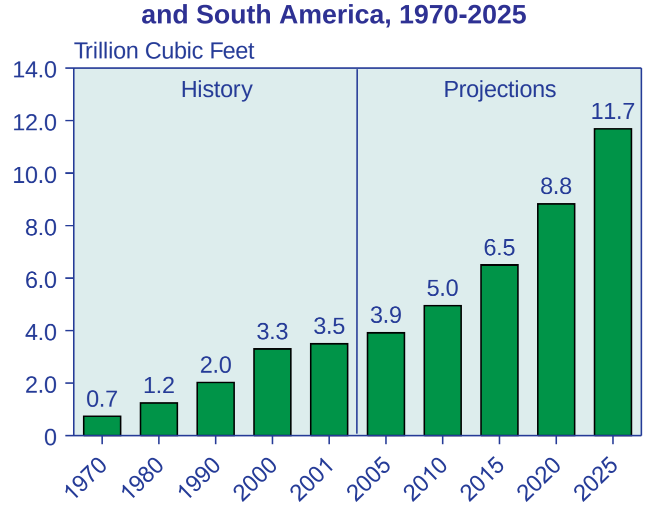
Although natural gas markets in Central and South America accounted for only 3.9 percent of the world's natural gas consumption in 2001, they are growing rapidly. Consumption in the region increased by 73 percent between 1990 and 2001, and *IEO2003* projects continuing growth of 5.2 percent per year over the forecast period, to 11.7 trillion cubic feet by 2025 (Figure 55). Currently, except for LNG exported from Trinidad and Tobago, all of Central and South America's natural gas production is consumed within the region, and indigenous production is sufficient to meet current demand.

Natural gas markets are still in the early stages of development in many Central and South American countries. Exploration activities continue to yield promising discoveries, and reserves increased from 245 trillion cubic feet at the end of 2000 to 253 trillion cubic feet at the end of 2001 [**129**]. The highest concentrations of reserves are in Argentina and Bolivia in the South and Venezuela and Trinidad and Tobago in the north. Venezuela's 148 trillion cubic feet of reserves far surpasses those of any other country in the region. The second highest concentration of reserves, 28 trillion cubic feet, is in Argentina. Other countries holding notable reserves, in order of amount, are Brazil, Colombia, and Ecuador.

Natural gas production in Central and South America as a whole increased by 3.7 percent from 2000 to 2001, led by production increases in Bolivia and Brazil of 21 and 13 percent, respectively. Trinidad and Tobago was the only major producer that reported a decrease, with production declining by 0.5 percent. Consumption increased throughout the region, led by Brazil with a 19.3-percent increase, Peru with a 7.1-percent increase, and Chile with a 6.5-percent increase. The overall growth of natural gas consumption in the region was 4.1 percent. The major trade movements were from Argentina to Chile and from Bolivia to Brazil, with Argentina also exporting to Brazil and Uruguay. Central America neither produced nor consumed any natural gas.

Although the region's natural gas markets have continued to grow overall, economic and political turmoil has had an impact on energy markets. The Argentine economic crisis, which led to a 29-percent currency devaluation in January 2002, continues and, along with the downward adjustment of salaries by both the government and private industry, has destroyed consumer confidence and brought a halt to the almost steady growth in consumption the country had experienced over the past decade. Argentina's natural gas industry is entirely in the hands of the private sector, but weakening domestic demand along with the struggling economy has made the private sector hesitant to invest further until conditions stabilize. As a result, the government's plans to attract foreign investment in Argentina's natural gas sector has slowed considerably [**130**].

Figure 55. Natural Gas Consumption in Central and South 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 (2003).

In Venezuela, a political strike, led by a coalition of union and management workers at the state oil and gas company PDVSA, began in early December 2002, protesting the Chavez government's interference in PDVSA's operations. The strike has put the government's plans to develop its natural gas sector in jeopardy. While repercussions in the oil sector, which accounts for 75 percent of Venezuela's exports, are much more severe than in the natural gas sector, they will delay plans for PDVSA to join a feasibility study on the Mariscal Sucre LNG project and for the government to restructure the natural gas sector and begin exploration and production of nonassociated gas [***131***]. Venezuela opened its downstream natural gas market to foreign investment in May 1998 and opened the exploration and development of nonassociated gas to foreign investment in August 1999. The Chavez administration's goal is to increase both production and consumption of natural gas in the near term. Because of the current political turbulence, however, foreign investors have backed off, and the government's plans to develop offshore gas fields have ground to a halt [***132***].

Brazilian state oil company Petrobras has been experiencing some economic problems resulting from its take-or-pay arrangements with the Bolivian state oil and gas company, YPFB. Making up the difference between contracted amounts and what has actually been taken is expected to cost between $50 and $60 million. Petrobras is also liable for payments for unused transport capacity it has contracted for on the export pipeline. The transport capacity liability could soon become significantly worse, because the transport capacity committed to by Petrobras is set to increase by 50 percent in March 2003. Bolivian producers and the Bolivian government are also not happy with the situation. Under the terms of the contract, producers must supply any undelivered volumes at the end of the contract in 2019; as a result, Bolivian producers are receiving money that cannot be registered as profit for a future liability. The government is unhappy with the fact that it is unable to tax payments that the producers receive for unsold gas [***133***].

South America's LNG market continues to grow. Venezuela has been trying for more than 20 years to enter the LNG market. The Mariscal Sucre LNG project is the successor to the Cristobal Colon project that was begun in 1990 in the hope of building a liquefaction train and exporting LNG beginning in 1997 but, like other Venezuelan LNG projects, was abandoned. The new Mariscal Sucre project will be held by PDVSA (60 percent), Shell (30 percent), and Mitsubishi (8 percent). The remaining 2 percent will be open to private investors in Venezuela. Mariscal Sucre consists of the development of four offshore fields with proven reserves of 4 trillion cubic feet and probable reserves of 10 trillion cubic feet and subsequent construction of a liquefaction facility beginning in 2004. The government's goal is 1 billion cubic feet per day, with 300 million cubic feet destined for local markets and the remainder for export [***134***].

The Mariscal Sucre project will be in direct competition with the Trinidad and Tobago liquefaction trains. Trinidad and Tobago has been exporting LNG since the first train at Atlantic LNG's Point Fortin facility became operational in 1999. In 2001, 32 percent of Central and South America's exports were in the form of LNG from Trinidad and Tobago, with 72 percent going to the United States, 16 percent to Puerto Rico, and the remaining 12 percent to Spain. Train 2 became operational in August 2002, and train 3 is under construction and expected to become operational by the second quarter of 2003. According to Atlantic LNG, the disposition of the output of the train 2 and train 3 expansions is to be 62 percent to the Spanish conventional and power markets and 38 percent to the U.S. market, primarily to the southeast through the Elba Island terminal. A fourth train is currently under consideration, and public consultations began in September 2002 to get feedback on the proposed additional train [***135***].

Bolivia is also attempting to enter the LNG market. In December 2001, the Pacific LNG consortium entered into a 20-year agreement with Sempra Energy for 800 million cubic feet per day of LNG to be exported from Bolivia to North America to serve Mexican and U.S. markets. The agreement called for the construction of a two-train liquefaction facility on the Pacific coast of South America. An extended debate has been going on as to whether the facility will be built along the coast of Peru or the coast of Chile. While the Chilean port seems to be the most viable economically, historical hatred of Chile by the Bolivians over land disputes has made negotiations difficult. The government's reluctance to make a decision, however, could jeopardize the project; and rumors imply that the government is about to announce the choice of the Chilean port of Patillos [***136***].

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135. "About Us: Train 4," Atlantic LNG Company of Trinidad and Tobago Web Page, web site www.atlanticlng.com (2002).

136. Andean Group, Latin American Newsletters, Ltd., *Latin America Regional Reports*, Section RA-03-01 (January 28, 2003), p. 5.

Coal

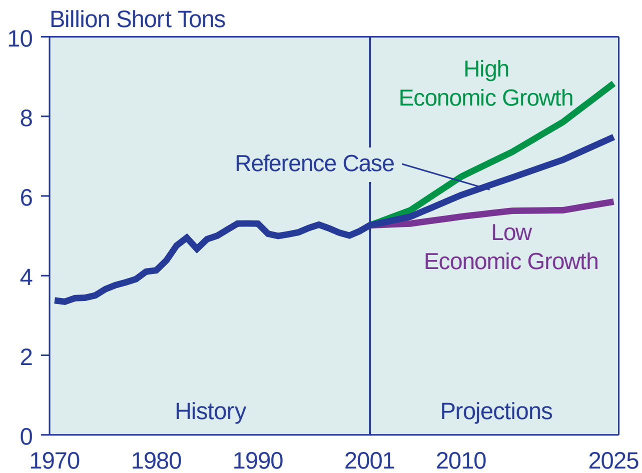
Although coal use is expected to be displaced by natural gas in some parts of the world, only a slight drop in its share of total energy consumption is projected by 2025. Coal continues to dominate many national fuel markets in developing Asia.

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,[12] 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 56). The *International Energy Outlook 2003* (*IEO2003*) reference case projects some 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 decline in Western Europe, Eastern Europe, and the former Soviet Union (FSU). Increases are expected in the United States, Japan, Australia, New Zealand, and developing Asia. 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 as a result of the economic collapse that followed the breakup of the Soviet Union, as well as some fuel switching. 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 *IEO2003* reference case, the coal share of total energy consumption is projected to fall to 22 percent by 2025 (Figure 57).

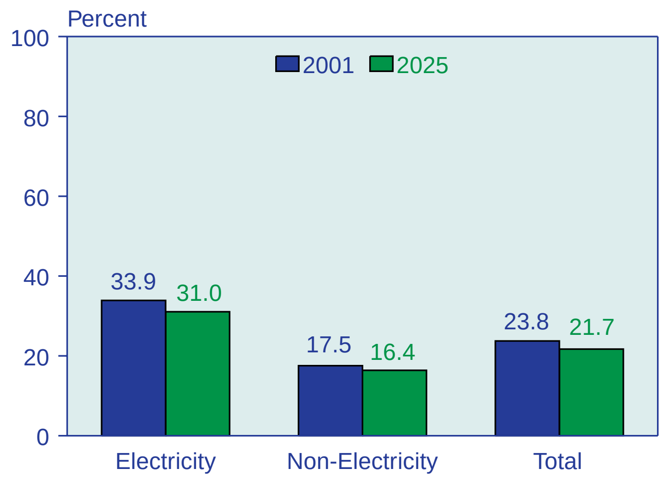
The expected decline in coal's share of energy use would be even greater were it not for large increases in energy use projected for developing Asia, where coal continues to dominate many fuel markets, especially in China and India. As very large countries in terms of both population and land mass, China and India are projected to account for 28 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 75 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 58).

Figure 56. 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 (2003).

Figure 57. Coal Share of World Energy Consumption by Sector, 2001 and 2025



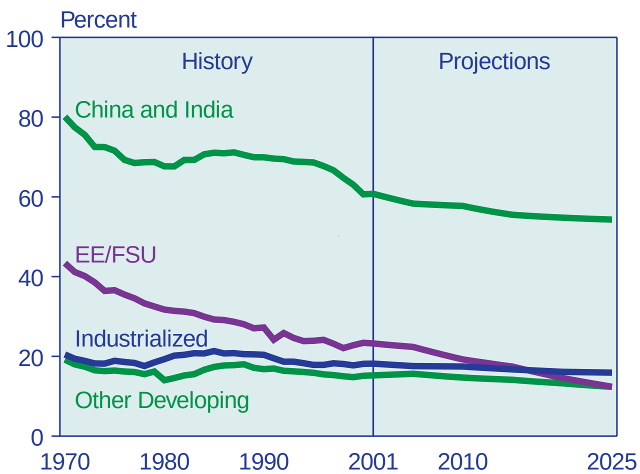
Sources: **2001:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **2025:** EIA, System for the Analysis of Global Energy Markets (2003).

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

Coal consumption is heavily concentrated in the electricity generation sector, and significant amounts are also used for steel production. Almost 55 percent of the coal consumed worldwide is used for electricity generation, and power generation accounts for virtually all the projected growth in coal consumption worldwide [*1*]. 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 *IEO2003* 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 assume compliance with the Kyoto Protocol, which currently is not a legally binding agreement. The implementation of plans and policies to reduce emissions of greenhouse gases could have a significant effect on coal consumption. For example, in an earlier study, the Energy Information Administration (EIA) projected that the United States could meet its Kyoto emissions target only by reducing annual coal consumption by between 18 percent and 77 percent (on a Btu basis) by 2010, depending on the level of international emission trading and domestic offsets assumed [*2*].

Figure 58. 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 (2003).

Developments in international coal markets are also important to the coal outlook. World coal trade grew by 46 million tons between 2000 and 2001, increasing to 650 million tons. In 2002, international coal markets were characterized by reduced growth in world coal trade relative to 2000 and 2001 and rising freight rates and coal export prices during the latter part of the year.

Highlights of the *IEO2003* projections for coal are as follows:

- World coal consumption is projected to increase by 2.2 billion tons, from 5.3 billion tons in 2001 to 7.5 billion tons in 2025. Alternative assumptions about economic growth rates lead to forecasts of world coal consumption in 2025 ranging from 5.9 to 8.8 billion tons (see Figure 56).

- Coal use in developing Asia alone is projected to increase by 1.9 billion tons. China and India together are projected to account for 28 percent of the total increase in energy consumption worldwide between 2001 and 2025 and 75 percent of the world's total projected increase in coal use, on a Btu basis.

- Coal-fired generating capacity in China is projected to increase by 60 percent, from 232 gigawatts in 2001 to 371 gigawatts in 2025. In India, coal-fired generating capacity is projected to increase by 45 percent, from 66 gigawatts in 2001 to 96 gigawatts in 2025.

- The share of coal in world total primary energy consumption is expected to decline from 24 percent in 2001 to 22 percent in 2025. The coal share of energy consumed worldwide for electricity generation is also projected to decline, from 34 percent in 2001 to 31 percent in 2025.

- World coal trade is projected to increase from 650 million tons in 2001 to 826 million tons in 2025, accounting for between 11 and 13 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.

Environmental Issues

Like other fossil fuels, coal has played an important role in fueling the advancement of civilization, but its use also raises environmental issues. Coal mining has a direct impact on the environment, affecting land and causing subsidence, as well as producing mine waste that must be managed. Coal combustion produces several types of emissions that adversely affect the environment, particularly ground-level air quality. Concern for the environment has in the past and will in the future contribute to policies that affect the consumption of coal and other fossil fuels. The main emissions from coal combustion are sulfur dioxide (SO_2), nitrogen oxides

(NO_x), particulates, carbon dioxide (CO_2), and mercury (Hg).

Sulfur dioxide emissions have been linked to acid rain, and many of the industrialized countries have instituted policies or regulations to limit them. Developing countries are also increasingly adopting and enforcing limits on sulfur dioxide emissions. Such policies typically require electricity producers to switch to lower sulfur fuels or invest in technologies—primarily flue gas desulfurization (FGD) equipment—that reduce the amounts of sulfur dioxide emitted with coal combustion.

Environmental regulation influences interfuel competition (i.e., how coal competes with other fuels, such as oil and natural gas), particularly in the power sector, where the competition is greatest. For example, compliance with increasingly stringent restrictions on emissions could be increasingly costly and could lead to reduced demand for coal. On the other hand, improved technologies may provide cost-effective ways to reduce emissions from coal-fired power plants. Integrated gasification combined-cycle (IGCC) technology, which may soon be commercially competitive, can increase generating efficiencies by 20 to 30 percent and also reduce emission levels (especially of carbon dioxide and sulfur oxides) more effectively than existing pollution control technologies [***3***].

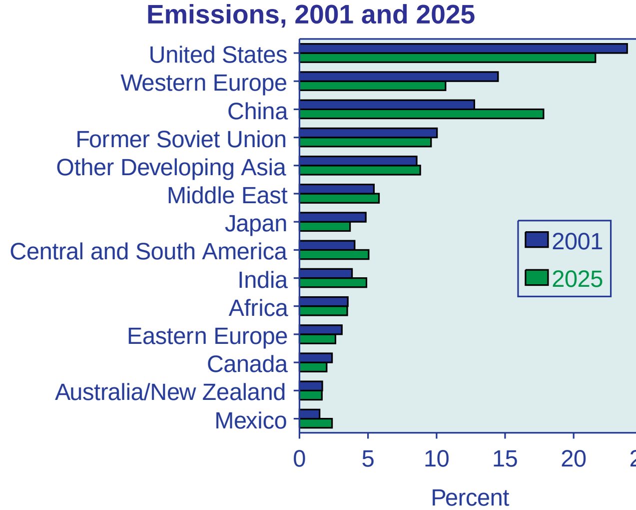
At the end of 1999, more than 280 gigawatts of coal-fired capacity around the world were equipped with FGD or other sulfur dioxide control technologies [***4***]. In the United States, 95 gigawatts of coal-fired generating capacity—30 percent of the U.S. total—was equipped with technologies to reduce sulfur dioxide emissions at the end of 1999 [***5***]. In the developing countries of Asia, only minor amounts of existing coal-fired capacity currently are equipped with desulfurization equipment. For example, in China, the world's largest emitter of sulfur dioxide, data for 1999 indicated that only about 2 percent of coal-fired generating capacity (at that time, less than 4 gigawatts out of a total of 207 gigawatts) had FGD equipment in place [***6***].

In addition to sulfur dioxide, increased restrictions on emissions of nitrogen oxides, particulates, and carbon dioxide are likely, especially in the industrialized countries. Although the potential magnitudes and costs of additional environmental restrictions for coal are uncertain, it seems likely that coal-fired generation worldwide will face steeper environmental cost penalties than will new natural-gas-fired generating plants. For nuclear and hydropower, which compete with coal for baseload power generation, the future is unclear. Proposals have been put forth in several of the developed countries to partially or fully phase out nuclear capacity. Countries where actual commitments have been made include Germany, Lithuania, and Sweden. In other countries, it has become difficult to site new capacity because of unfavorable public reaction. The siting of new large hydroelectric dams is also becoming more difficult because of increased environmental scrutiny. In addition, suitable sites for new large hydropower projects in the industrialized countries are limited [***7***].

By far the most significant issue for coal is emissions of carbon dioxide. On a Btu basis, the combustion of coal produces more carbon dioxide than the combustion of natural gas or of most petroleum products (combustion of petroleum coke produces slightly more carbon dioxide per unit of heat input than does combustion of coal). Carbon dioxide emissions per unit of energy obtained from coal are nearly 80 percent higher than those from natural gas and approximately 20 percent higher than those from residual fuel oil, which is the petroleum product most widely used for electricity generation [***8***].

In 2001, the United States and China were the world's dominant coal consumers and also the two top emitters of carbon dioxide, accounting for 24 percent and 13 percent, respectively, of the world's total emissions. Different economic growth rates and shifting fuel mixes explain in part why the U.S. share of world carbon emissions is projected in the *IEO2003* forecast to decline to 22 percent by 2025, while China's share is projected to increase to 18 percent (Figure 59). Worldwide, coal is projected to continue as the second largest source of carbon dioxide emissions (after petroleum), accounting for 34 percent of the world total in 2025.

Figure 59. Regional Shares of World Carbon Emissions, 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 (2003).

Reserves

Total recoverable reserves of coal around the world are estimated at 1,083 billion tons[13]—enough to last approximately 210 years at current consumption levels (Figure 60). Although coal deposits are widely distributed, 60 percent of the world's recoverable reserves are located in three regions: the United States (25 percent), FSU (23 percent), and China (12 percent). Another four countries—Australia, India, Germany, and South Africa—account for an additional 29 percent. In 2001, these seven regions accounted for 80 percent of total world coal production [*9*].

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 84 percent of the coking coal traded worldwide in 2001 (see Table 19 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 raises transportation costs 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) [*10*]. 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 1999 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 4.7 million Btu per ton in Greece to a high of 12.3 million Btu per ton in Canada [*11*]. In comparison, premium coal supplied to United States coke plants is estimated to have a content of 27.4 million Btu per ton [*12*].

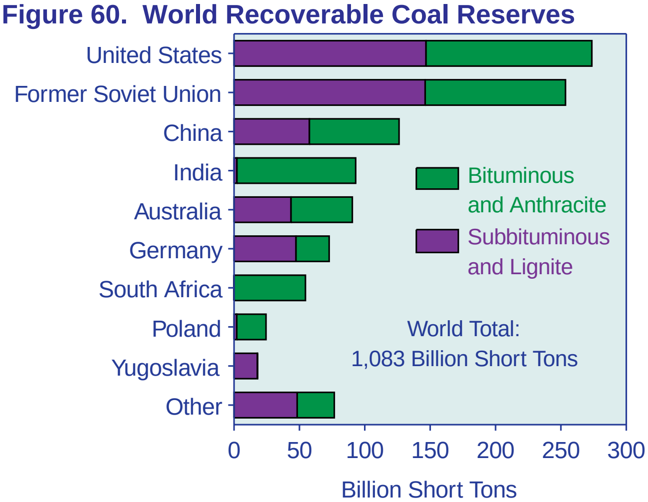
Regional Consumption

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 53-percent share of total world coal consumption by 2025.

The large increases in coal consumption projected for China and India (Figure 61) are based on an outlook for strong economic growth (6.2 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

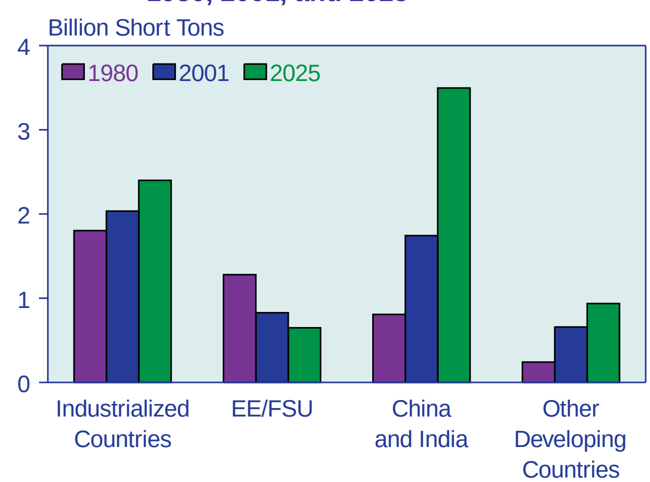
Figure 60. World Recoverable Coal Reserves



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 61. 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 (2003).

[13]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.

industrial and electricity sectors. The *IEO2003* forecast assumes no significant changes in environmental policies in the two countries. It also assumes that necessary investments in the countries' mines, transportation, industrial facilities, and power plants will be made.

In China, 62 percent of the coal demand in 2001 occurred in the non-electricity sectors, for steam and direct heat for industrial applications (primarily in the chemical, cement, and pulp and paper industries), and for the manufacture of coal coke for input to the steelmaking process. Although China's coal demand in the non-electricity sectors is expected to increase by 12 quadrillion Btu over the forecast period, the non-electricity share of total coal demand is projected to decline to 52 percent by 2025. In 2000, China was the world's leading producer of both steel and pig iron [***13***].

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 government recently has signed an agreement with Hydrocarbon Technologies, Inc., to build a direct coal liquefaction plant in China beginning in 2003, with an expected startup in 2005. The $2 billion facility will be located in Inner Mongolia and will have an ultimate capacity of 50,000 barrels per day produced from local coal. The agreement is for three units, which together will consume 5 million tons of coal annually [***14***]. Compared with South Africa's most recently constructed coal liquefaction plant (built by SASOL at Secunda, South Africa, in 1982), which is capable of producing more than 25 million barrels of coal liquids annually, China's first plant will be smaller, with an annual production capacity of approximately 18 million barrels.

In China's electricity sector, coal use is projected to grow by 4.2 percent a year, from 9.8 quadrillion Btu in 2001 to 26 quadrillion Btu in 2025. In comparison, coal consumption by electricity generators in the United States is projected to rise by 1.2 percent annually, from 20.9 quadrillion Btu in 2001 to 27.7 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 140 gigawatts of additional coal-fired capacity by 2025.[14] At the beginning of 2001, China had 232 gigawatts of coal-fired generating capacity [***15***].

The debate as to whether China will become a major coal exporter (because of its relatively inexpensive mining costs) or a major coal importer (because of anticipated growth in its coal use over time) has yet to be determined. In either case, however, the completion of two major non-coal infrastructure projects near the end of the decade should reduce domestic coal demand and free up more production for export. The first infrastructure improvement, a new west-to-east transmission line that will allow hydropower from the Three Gorges Dam complex to be wheeled to load centers in eastern and southern China, will in all probability result in the displacement of coal-fired generation at small older plants. The second infrastructure improvement, a new pipeline that will bring natural gas from northwest China to eastern and southern provinces, will likely displace coal used in industrial boilers and some utility generation [***16***].

In India, projected growth in coal demand occurs primarily in the electricity sector, which currently accounts for almost three-quarters of India's total coal consumption. Coal use for electricity generation in India is projected to rise by 2.1 percent per year, from 4.1 quadrillion Btu in 2001 to 6.7 quadrillion Btu in 2025, implying that India will need to build approximately 30 gigawatts of additional coal-fired capacity.[15] At the beginning of 2001, India's total coal-fired generating capacity amounted to 66 gigawatts [***17***].

India's state-owned National Thermal Power Corporation (NTPC) is the largest thermal power generating company in India. At present, it has 16,220 megawatts of coal-fired capacity that rely almost exclusively on India's state-owned coal producer, Coal India Limited (CIL), for its supply of coal. 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 [***18***].

[14] 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 2003* reference case forecast, U.S. coal-fired power plants are projected to consume an average of 73 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 33.5 percent.

[15] 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 remaining 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 0.3 percent per year, from 2.2 quadrillion Btu in 2001 to 2.4 quadrillion Btu in 2025.

The key motivation for increasing use of coal in other developing Asia is diversity of fuel supply for electricity generation [**19**]. This objective exists even in countries that have abundant reserves of natural gas, such as Thailand, Malaysia, Indonesia, and the Philippines. In the *IEO2003* forecast, coal's share of fuel consumption for electricity generation in the region is projected to decline from 22 percent in 2001 to 13 percent by 2025.

Some of the planned additions of coal-fired generating capacity in other developing Asia for 2003 and later include 5,400 megawatts of new coal-fired capacity for South Korea by 2015, 4,900 megawatts for Malaysia by 2006, and 1,400 megawatts for Thailand by 2009 [**20**]. In addition to planned capacity additions, a number of new coal-fired units have come on line in the region between 1999 and 2002, adding a combined total of more than 15,000 megawatts of electric power supply in South Korea (4,600 megawatts), Taiwan (4,215 megawatts), Indonesia (2,450 megawatts), Malaysia (1,700 megawatts), and the Philippines (2,040 megawatts) [**21**]. In Indonesia, however, several large coal-fired plants that have been completed recently or are near completion (Paiton I, Paiton II and Tanjung Jati-B) await new transmission capacity, which will not be fully completed until 2005 [**22**].

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 Malaysia. 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 [**23**]. Recently, the Electricity Generating Authority of Thailand (EGAT) decided to delay purchasing power from three coal-fired plants for 3 years. This decision will delay the startup of a 1,364-megawatt project constructed by BLCP Power (a consortium of energy companies) until 2009 and may also significantly affect the development of the Bo Nok and Hin Krut plants, both of which have faced heavy opposition from local residents and environmental groups [**24**].

Industrialized Asia

Industrialized Asia consists of Australia, New Zealand, and Japan. Australia is the world's leading coal exporter and Japan is the leading coal importer in the world. In 2001, Australian coal producers shipped 214 million tons of coal to international consumers, and another 144 million tons of Australian coal (both hard coal and lignite) was consumed domestically, primarily for electricity generation. Coal-fired power plants accounted for 77 percent of Australia's total electricity generation in 2001 [**25**]. Over the forecast horizon, coal use in Australia is expected to increase slightly. At present, Australia's Queensland district has three new coal-fired power projects in various stages of completion: Callide C power plant (840 megawatts of capacity brought on line in 2001), Millmerran plant (840 megawatts of capacity brought online in 2002), and Tarong Power plant (450 megawatts scheduled for early 2003) [**26**]. 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 [**27**].

Japan, which is the third largest coal user in Asia and the seventh largest globally, imports nearly all the coal it consumes, much of it originating from Australia [**28**]. Japan's last two underground coal mines, Ikeshima with an annual production capacity of 1.1 million tons and Taiheiyo with a capacity of 2.2 million tons, were closed in late 2001 and early 2002 [**29**]. 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) [**30**]. Coal is also used heavily in the Japanese power sector, and coal-fired plants currently generate approximately 25 percent of the country's electricity supply [**31**]. Japanese power companies plan to construct an additional 16 gigawatts of new coal-fired generating capacity between 2001 and 2010 [**32**].

Western Europe

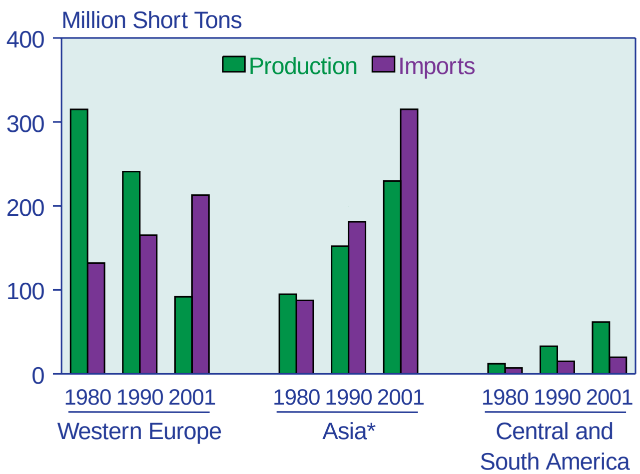
In Western Europe, environmental concerns play an important role in the competition among coal, natural gas, and nuclear power. Recently, other fuels—particularly, natural gas—have been gaining economic advantage over coal. Coal consumption in Western Europe has fallen by 36 percent since 1990, from 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 22 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.

The European Commission has proposed that a new state aid scheme for coal be established to allow for the continuation of subsidies for hard coal production in member states through December 31, 2010 [33]. In essence, the Commission wants to establish measures that will promote the development of renewable energy sources as well as maintain a minimum capacity of subsidized coal production in the European Union for the purpose of establishing an "indigenous primary energy base." Under this new scheme, the guiding principle for coal will be that subsidized production will be limited to that which is strictly necessary for enhancing the security of energy supply (i.e., to maintain access to coal reserves, keep equipment in an operational state, preserve the professional qualifications of a nucleus of coal miners, and safeguard technological expertise).

The recent trend in the consumption of hard coal[16] in Western Europe is closely correlated with the trend in the production of hard coal, primarily because coal imports have increased by much less than production has declined (Figure 62). 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)

Figure 62. Production and Imports of Hard Coal by Region, 1980, 1990, and 2001



*Data for Asia exclude Australia, China, India, and New Zealand.

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

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/.

continue to produce hard coal [34], and all have seen their output of hard coal decline since 1990. In the near future, the proposed enlargement of the European Union would add two additional producers of hard coal, Poland and the Czech Republic [35].

Hard coal production in the United Kingdom decreased from 104 million tons in 1990 to 35 million tons in 2001, a decline of 69 million tons [36]. During the same period, coal consumption fell by 48 million tons. Most of the decline in coal consumption resulted from privatization in the electricity sector, which led to a rapid increase in natural-gas-fired generation at the expense of coal.

The massive switch to natural gas and its adverse impact on the country's coal industry prompted the British government, in mid-1998, to place a moratorium on the construction of new gas-fired plants and, at the same time, request that a study be completed to assess the state of the country's electric power industry [37]. The two key issues to be investigated were the design, operation, and structure of the country's wholesale electricity market and the diversity and security of fuel supplies for electricity generation. As a result of the study, revisions in the setup of the country's wholesale electricity market were introduced, primarily aimed at introducing competition into the market for electricity generation.

The revised electricity market, referred to as the New Electricity Trading Arrangements (NETA), went into effect on March 27, 2001, and the moratorium on the construction of new gas-fired generating plants was lifted in November 2000 [38]. As of early 2003, NETA has been successful to the extent that the United Kingdom has realized substantial declines in both wholesale and retail electricity prices [39]. Under the country's former electricity market, referred to as the Electricity Pool, wholesale electricity prices failed to fall despite an estimated 50-percent decline in generation costs between 1990 and 2000. On the other hand, coal-fired generators have faired somewhat poorly under NETA, with lower cost generation effectively forcing the mothballing of several older coal-fired plants during 2002. Some UK generators indicate that wholesale electricity prices have essentially fallen to a level that is below the cost of production, while others argue that NETA has allowed the market to work and that what is occurring now is simply a weeding out of the most inefficient, high-cost electricity plants [40]. (For further discussion on NETA, see pages 149-151 in the Electricity chapter.)

Currently, the United Kingdom's remaining coal mines are by far the most productive hard coal operations in Western Europe. Substantial improvements in the country's mining operations in recent years have led to an

[16] 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.

increase in average labor productivity from 1,190 tons per miner-year in 1990 to 3,200 tons per miner-year in 1999 [**41**]. Despite this achievement, the price of coal from domestic mines is essentially at parity with the price of coal imports, and it is likely that production from domestic mines will continue to be sensitive to changes in international coal prices [**42**]. In fact, following several years of sharp declines in international coal prices in 1998 and 2000, the UK government reinstated coal production subsidies for 2000 through 2002 in an effort to protect the country's remaining coal operations (Table 18) [**43**].

In Germany, Spain, and France, subsidies continue to support the domestic production of hard coal,[17] even though there is no hope that their production will ever be competitive with imports. The European Commission authorized coal industry subsidies for 2001 of $4,643 million in Germany, $1,194 million in Spain, and $1,073 million in France [**44**]. In each of the three countries, the average subsidy per ton of coal produced exceeds the average value of imported coal (Table 18), and all three are currently taking steps to reduce subsidy payments, acknowledging that some losses in coal production are inevitable.

Germany's hard coal production declined from 86 million tons in 1990 to 32 million tons in 2001 [**45**]. In late 1999, the Supervisory Board of RAG Aktiengesellschaft—an international mining and technology group based in Essen, Germany—agreed to speed up the pace of restructuring, because declining prices for hard coal in the world market and the severe drop in coal demand for steel production resulted in additional costs for the company beyond those covered by the existing subsidy granted by the German government. The revised restructuring agreement calls for an additional reduction in Germany's coal production to 26 million tons by 2005, to be achieved by further mergers. The net result of all planned mergers: a capacity reduction of 8.2 million tons and the loss of over 10,000 jobs [**46**]. The closure of three coal mines in 2000 (with a combined production capacity of approximately 6.7 million tons) leaves Germany with only 10 remaining hard coal mines in operation [**47**].

Between 1990 and 2001, German lignite production declined by 234 million tons, primarily as a result of massive substitution of natural gas for both lignite and lignite-based "town gas"[18] in the eastern states following reunification in 1990 [**48**]. The collapse of industrial output in the eastern states during the same period was a contributing factor. In the *IEO2003* reference case, Germany's coal consumption is projected to remain steady until 2005, after which it begins falling again, although not as dramatically as in recent years. By 2025, coal use in Germany is projected to be 203 million tons, a drop of 62 million tons from the 2001 level of 265 million tons.

In Spain, hard coal production declined from 22 million tons in 1990 to 16 million tons in 2001 [**49**]. Spain has adopted a restructuring plan for 1998 through 2005 that provides for a gradual decline in production to 12 million tons [**50**]. In addition to hard coal, two lignite mines in Spain, which produced 9 million tons in 2001, are earmarked for closure within the next 3 to 4 years [**51**]. Currently, the two generating plants that burn the lignite produced by the mines also rely in part on imports of subbituminous coal. Both plants are expected to increase their take of imported coal over the forecast, as lignite production from the two mines is ramped down.

In France, production of hard coal declined from 12 million tons in 1990 to 2 million tons in 2001 [**52**]. A modernization, rationalization, and restructuring plan submitted by the French government to the European Commission at the end of 1994 foresees the closure of all coal mines in France by 2005 [**53**]. The coal industry

Table 18. 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	4,643	32.4	144	43
Spain	1,194	15.9	75	40
France	1,073	2.2	494	47
United Kingdom	91	34.7	3	47

Sources: **Coal Production Subsidies:** Commission of the European Communities, *Report From the Commission on the Application of the Community Rules for the State Aid to the Coal Industry in 2001* (Brussels, Belgium, July 2, 2002), p. 10, web site www.europa.eu.int; and U.S. Federal Reserve Bank, "Foreign Exchange Rates (Annual)," web site www.federalreserve.gov (January 6, 2003). **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 2002* (Paris, France, September 2002), and *Energy Prices & Taxes, Quarterly Statistics, Fourth Quarter 2002* (Paris, France, January 2003).

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

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

restructuring plan was based on a "Coal Agreement" between France's state-run coal company, Charbonnages de France, and the coal trade unions.

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 [***54***]. In 2001, 47 percent of Denmark's electricity was supplied by coal-fired plants [***55***]. Coal consumption in Italy is projected to decline from 22 million tons in 2001 to 18 million tons in 2025 in the *IEO2003* forecast, although an increase of 3 to 5 million tons per year is possible if Enel, Italy's dominant electricity company, completes its plan to boost coal use to 20 percent of its power generation by 2005-2006, by switching high-cost oil plants to lower cost coal plants [***56***].

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 an agreement reached by the countries of the European Union in June 1998, Greece committed to capping its emissions of greenhouse gases by 2010 at 25 percent above their 1990 level—a target that is much less severe than the emissions target for the European Union as a whole, which caps emissions at 8 percent below 1990 levels by 2010 [***57***].

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 548 million tons since 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 *IEO2003* reference case, coal's share of total EE/FSU energy consumption is projected to decline from 23 percent in 2001 to 12 percent in 2025, and the natural gas share is projected to increase from 45 percent in 2001 to 57 percent in 2025.

The three main coal-producing countries of the FSU—Russia, Ukraine, and Kazakhstan—are facing similar problems. The three countries have developed national programs for restructuring and privatizing their coal industries, but they have been struggling with related technical and social problems. Between 1990 and 2001, coal production declined by 72 million tons (19 percent) in Russia, by 79 million tons (47 percent) in Ukraine, and by 42 million tons (32 percent) in Kazakhstan [***58***]. Although 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, 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 have been purchased by, and are now operated by, international energy companies [***59***]. In Russia, the World Bank estimates that 77 percent of the country's coal production in 2001 will 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 [***60***].

In Ukraine, a coal restructuring program initiated by the government in 1996, with advice and financial support provided by the World Bank, has been mostly unsuccessful in rejuvenating the industry. Key problems that continue to plague the Ukrainian coal industry are that: (1) most of the country's mines continue to be highly subsidized, government-run enterprises; (2) dangerous working conditions prevail (several catastrophic mine disasters have occurred in the past several years); (3) wage arrears continue to be a serious problem, with miners currently owed back wages of approximately $3.5 billion; (4) productivity is very low due to antiquated mining equipment and the extreme depths at which coal is extracted (only three of Ukraine's active coal mines are surface operations); and (5) nonpayment for coal by customers is rampant [***61***].

The World Bank has focused its efforts in Ukraine on trying to convince the government that it needs to close additional unprofitable mines [***62***]. In 2001, a spokesperson for the World Bank expressed his belief that an additional 50 to 60 of the country's remaining coal mines need to be closed [***63***]. Others indicate that problems with the Ukrainian coal industry will not be solved simply through the closure of the least economical mines. They point to delays in privatization of coal mining operations, widespread corruption and abuse in the coal sector, worsening geological conditions, and misdirection of government subsidies (e.g., not enough of the government subsidies have been directed toward equipment upgrades at existing mines). Most recently, the Ukrainian government indicated that it would not formally present a plan to privatize the coal industry until after 2003 [***64***].

Recent data showing a slight resurgence in coal production in the FSU since 1998, particularly in Russia and Kazakhstan, in combination with draft energy strategies for Russia and Ukraine, indicate an optimistic long-term outlook for both coal production and consumption [***65***]. The *IEO2003* outlook for FSU coal consumption, however, is for an increase until 2005 and then a declining trend over time. Natural gas and oil are expected to fuel most of the projected increase in energy consumption for the region.

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 [66]. In 2001, coal consumption in Poland totaled 151 million tons, 47 percent of Eastern Europe's total coal consumption for the year [67]. Poland's hard coal industry produced 113 million tons in 2001, and lignite producers contributed an additional 66 million tons. 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 summing to a little more than 3 million short tons in 2000 [68].

Poland's hard coal industry operated at a slight loss in 2001, but it is expected to operate in the black in 2002 [69]. Over the past several years, a number of coal industry restructuring plans have been put forth for the purpose of transforming Poland's hard coal industry to a position of positive earnings, eliminating the need for government subsidies. The most recent plan for Poland's final phase of coal industry reorganization was announced in November 2002. Under the 3-year plan, employment would be reduced to 100,000 workers by 2006, and seven coal mines would be scheduled for closure. That would leave Poland with 31 mines capable of producing 87 million tons of coal per year, eliminating the traditional surplus (3 million tons in 2002) along with a large portion of the heavily state-subsidized coal export business, which receives more than $10 for each ton of coal exported [70]. The 13 trade unions involved in Poland's coal industry are opposed to the proposed final phase, however, and now the Polish government has agreed to defer its decision on pit closures and to maintain the coal miners' traditional social benefits [71].

The Polish government projects that sales of hard coal from domestic mines will decline from 100 million tons in 1998 to 77 million tons by 2025. As of August 2001, the World Bank had approved a total of $400 million in hard coal sector adjustment loans in support of the Polish government's restructuring program. The most recent loan, in the amount of $100 million (referred to as the Second Hard Coal Sector Adjustment Loan, or SECAL 2) was designed to support the implementation of the Polish government's Revised Hard Coal Sector Reform Program. It will support capacity and financial restructuring, environmental improvements, privatization, and social monitoring [72].

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. By 2025 U.S. consumption is projected to rise to 1,444 million tons. 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 47 percent in 2025 [73]. To a large extent, EIA's projections of declines in both minemouth coal prices and coal transportation rates are the basis for the expectation that coal will continue to compete as a fuel for U.S. power generation. Increases in coal-fired generation are projected to result from both greater utilization of U.S. coal-fired generating capacity and the addition of 65 gigawatts of new coal-fired power plants by 2025. Over the forecast period, the average utilization rate of coal-fired generating capacity is projected to rise from 69 percent in 2001 to 83 percent by 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 (four at Ontario Power's Pickering A plant and two at Bruce Power's Bruce A plant) over the next few years is expected to restrain the need for coal in eastern Canada. A committee of the provincial legislature on alternative fuel sources recently recommended that Ontario eliminate all coal-fired generation within the next 13 years. The Ontario government appeared to support this proposal by vetoing the sale of Ontario Power's Thunder Bay and Antikokan coal facilities in Northern Ontario, which now account for 25 percent of the Province's electricity output, and hinting that they could be mothballed after 2015 [74]. The leader of Ontario's Liberal Party has been even more aggressive, pledging to replace all coal-fired power with natural gas and renewable energy within 5 years if his party wins the next election, scheduled to be held in late 2003 or early 2004 [75].

In western Canada, increased demand for electricity is expected to result in the need for some additional coal-fired generation [76]. 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 [77]. 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 TransAlta at its Keephills coal facility (900 megawatts), scheduled for operation in 2005, and by a joint EPCOR-TransAlta investment in EPCOR's Genesee Phase 3 project (450 megawatts), scheduled for operation in winter 2004-2005 [78]. In Saskatchewan, SaskPower is currently rebuilding its coal-fired Boundary Dam Unit 6 at Estevan, extending its life by an additional 20 to 25 years. The rebuild, which will include a new scrubber system to reduce sulfur dioxide emissions, should be complete by July 1, 2003 [79].

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 Comision Federal de Electricidad (CFE), consume approximately 10 million tons of coal annually, most of which originates from domestic mines [80]. 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 [81]. 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 [82].

Although natural gas is expected to fuel most new generating capacity to be built in Mexico over the *IEO2003* forecast period, some new coal-fired generation is also expected. Several manufacturing companies, such as Kimberly Clark and steelmakers Ispat and Altos Hornos de Mexico, are exploring the possibility of constructing some coal-fired plants near their production facilities [83]. The plants would be developed under Mexico's new self-supply provisions, which allow private power producers and large industrials the option of bypassing state-owned CFE as long as the industrial end users hold equity stakes in the projects [84]. In addition, based on authorization granted by the government's energy authority in 2001, the CFE is considering the possibility of constructing a new coal-fired plant on Mexico's Pacific coast [85].

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 [86]. 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 [87].

For Africa as a whole, coal consumption is projected to increase by 103 million tons between 2001 and 2025, primarily to meet increased demand for electricity, which is projected to increase at a rate of 3.0 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 [88]. 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 [89]. Also, Tanzania may move ahead on 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 [90].

A recently completed coal project in Africa was 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 [91].

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 3.8 percent of the region's total energy consumption, and in years past 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 [92]. 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 [93].

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 [**94**]. 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 [**95**].

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 country's dependence on oil for electricity generation [**96**]. The 454-megawatt circulating fluidized bed (CFB) plant, located in Guayama, will require approximately 1.5 million tons of imported coal annually [**97**].

Middle East

Turkey accounts for almost 86 percent of the coal consumed in the Middle East. In 2001, Turkish coal consumption reached 81 million tons, most of it low-Btu, locally produced lignite (approximately 6.8 million Btu per ton) [**98**]. Over the forecast period, coal consumption in Turkey (both lignite and hard coal) is projected to increase by 40 million tons, primarily to fuel additional coal-fired generating capacity. Projects currently in the construction phase include a 1,210-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 [**99**]. When completed between 2003 and 2005, the two plants could add more than 10 million tons to Turkey's annual coal consumption.

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 [**100**]. 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 [**101**].

Trade

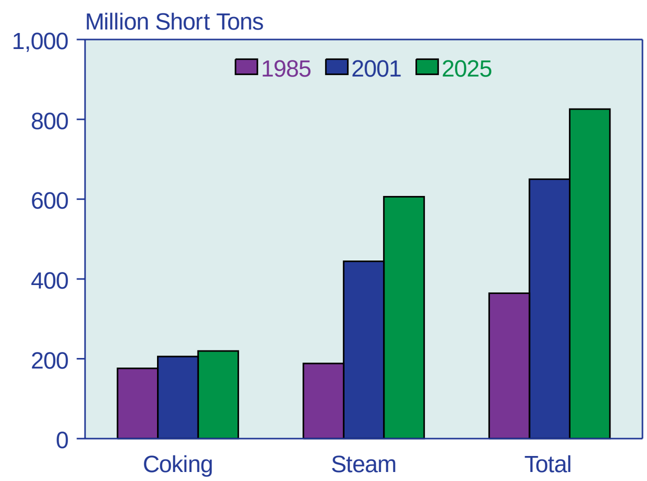
Overview

The amount of coal traded in international markets is small in comparison with total world consumption. In 2001, world imports of coal amounted to 650 million tons (Figure 63 and Table 19), representing 12 percent of total consumption. By 2025, coal imports are projected to rise to 826 million tons, accounting for an 11-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 relatively stable demand for coal imports in Western Europe and expanding demand in Asia (see Figure 62). 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, creating the potential for significant increases in coal imports; however, environmental concerns and increased electricity generation from natural gas, nuclear, and hydropower have curtailed the growth in coal imports. Conversely, growth in coal demand in Japan, South Korea, and Taiwan in recent years has contributed to a substantial rise in Asia's coal imports.

Most recently, in 2001 and 2002, international coal markets have undergone some significant changes on both the supply and demand sides. In 2001, international coal markets were affected by several factors, including a sharp decline in ocean freight rates from 2000, further

Figure 63. World Coal Trade, 1985, 2001, 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. 11, No. 4 (London, UK, September 2002); Energy Information Administration, *Quarterly Coal Report*, DOE/EIA-0121(2001/4Q) (Washington, DC, May 2002); and Statistics Canada, *Coal and Coke Statistics—December 2001*, Catalogue 45-002-XIB, Vol. 80, No. 12 (Ottawa, Canada, March 2002). **2025:** Energy Information Administration, National Energy Modeling System run IEO2003.D033103A (March 2003).

Table 19. World Coal Flows by Importing and Exporting Regions, Reference Case, 2001, 2010, and 2025
(Million Short Tons)

Exporters	Importers											
	Steam[a]				Coking				Total			
	Europe[b]	Asia	America	Total[c]	Europe[b]	Asia[d]	America	Total[c]	Europe[b]	Asia	America	Total[c]
	2001											
Australia	9.5	85.2	2.0	**97.1**	31.4	78.9	6.6	**117.1**	40.9	164.1	8.6	**214.2**
United States	6.4	2.8	14.0	**23.3**	15.7	0.4	9.3	**25.4**	22.1	3.2	23.3	**48.7**
South Africa	62.4	8.5	2.1	**74.7**	0.7	0.1	0.3	**1.5**	63.1	8.6	2.4	**76.2**
Former Soviet Union	18.5	7.1	0.0	**25.8**	0.7	2.8	0.0	**3.6**	19.2	9.9	0.0	**29.4**
Poland	18.1	0.0	0.6	**18.7**	2.1	0.0	0.0	**2.1**	20.2	0.0	0.6	**20.8**
Canada	0.0	2.3	1.1	**3.5**	7.3	16.6	5.1	**30.1**	7.3	18.9	6.2	**33.6**
China	5.3	80.4	1.8	**87.5**	0.3	11.6	0.8	**12.7**	5.6	92.0	2.6	**100.2**
South America[e]	29.5	0.0	20.4	**49.8**	0.0	0.0	0.0	**0.0**	29.5	0.0	20.4	**49.8**
Indonesia[f]	12.0	49.5	2.3	**63.8**	0.1	13.0	0.0	**13.1**	12.1	62.5	2.3	**76.9**
Total	**161.8**	**235.8**	**44.3**	**444.3**	**58.2**	**123.4**	**22.1**	**205.7**	**220.0**	**359.2**	**66.4**	**650.0**
	2010											
Australia	11.1	120.7	0.4	**132.2**	33.5	83.9	9.5	**127.0**	44.6	204.6	10.0	**259.2**
United States	3.8	2.2	7.6	**13.7**	10.3	1.3	9.5	**21.1**	14.2	3.5	17.1	**34.8**
South Africa	73.6	6.8	2.6	**83.0**	1.3	0.3	0.0	**1.7**	74.9	7.1	2.6	**84.7**
Former Soviet Union	22.4	6.8	0.0	**29.2**	0.2	4.3	0.0	**4.5**	22.6	11.1	0.0	**33.7**
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	6.0	0.0	0.0	**6.0**	12.4	7.8	8.4	**28.6**	18.4	7.8	8.4	**34.5**
China	0.0	113.5	0.0	**113.5**	0.0	15.8	0.0	**15.8**	0.0	129.3	0.0	**129.3**
South America[e]	38.6	0.0	32.6	**71.2**	0.0	0.0	0.0	**0.0**	38.6	0.0	32.6	**71.2**
Indonesia[f]	13.7	68.6	0.0	**82.3**	0.0	11.8	0.0	**11.8**	13.7	80.4	0.0	**94.1**
Total	**178.3**	**318.7**	**43.3**	**540.3**	**58.9**	**125.2**	**27.4**	**211.5**	**237.3**	**443.9**	**70.7**	**751.8**
	2025											
Australia	2.9	146.9	1.0	**150.8**	32.2	90.3	13.3	**135.9**	35.1	237.2	14.3	**286.6**
United States	0.0	2.3	6.1	**8.4**	7.2	0.4	5.6	**13.1**	7.2	2.7	11.7	**21.5**
South Africa	70.4	14.8	3.8	**89.0**	0.8	0.3	0.0	**1.1**	71.1	15.1	3.8	**90.1**
Former Soviet Union	23.7	8.5	0.0	**32.2**	0.2	5.0	0.0	**5.2**	23.9	13.4	0.0	**37.3**
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**	8.9	9.0	9.7	**27.7**	10.4	9.0	9.7	**29.2**
China	0.0	121.3	0.0	**121.3**	5.3	16.3	2.7	**24.3**	5.3	137.6	2.7	**145.5**
South America[e]	59.0	0.0	42.6	**101.5**	0.0	0.0	0.0	**0.0**	59.0	0.0	42.6	**101.5**
Indonesia[f]	0.0	97.1	0.0	**97.1**	0.0	11.8	0.0	**11.8**	0.0	108.9	0.0	**108.9**
Total	**161.9**	**390.7**	**53.5**	**606.1**	**55.0**	**133.2**	**31.4**	**219.6**	**216.9**	**523.9**	**84.8**	**825.7**

[a]Reported data for 2001 are consistent with data published by the International Energy Agency (IEA). The standard IEA definition for "steam coal" includes coal used for pulverized coal injection (PCI) at steel mills; however, some PCI coal is reported by the IEA as "coking coal."

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

[c]In 2001, total world coal flows include a balancing item used by the International Energy Agency to reconcile discrepancies between reported exports and imports. The 2001 balancing items by coal type were 2.5 million tons (steam coal), 1.9 million tons (coking coal), and 4.4 million tons (total).

[d]Includes 12.0 million tons of coal for pulverized coal injection at blast furnaces shipped to Japanese steelmakers in 2001.

[e]Coal exports from South America are projected to originate from mines in Colombia and Venezuela.

[f]In 2001, coal exports from Indonesia include shipments from other countries not modeled for the forecast period. The 2001 non-Indonesian exports by coal type were 2.3 million tons (steam coal), 1.3 million tons (coking coal), and 3.6 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: **2001:** SSY Consultancy and Research, Ltd., *SSY's Coal Trade Forecast*, Vol. 11, No. 4 (London, UK, September 2002); Energy Information Administration, *Quarterly Coal Report*, DOE/EIA-0121(2001/ 4Q) (Washington, DC, May 2002); and Statistics Canada, *Coal and Coke Statistics—December 2001*, Catalogue 45-002-XIB, Vol. 80, No. 12 (Ottawa, Canada, March 2002). **2010 and 2025:** Energy Information Administration, National Energy Modeling System run IEO2003.D033103A (March 2003).

recovery in coal export prices (FOB port of exit) from lows reached in 1999 and early 2000, a continuation of strong growth in coal import demand, and a continuing surge in coal exports from China [**102**].

World coal trade increased by 7.7 percent in 2001, compared with increases of 10.0 percent in 2000 and 0.4 percent in 1999. All the major demand regions (Europe, Asia and the Americas) posted increases for the year. In Europe, the overall increase in coal imports in 2001 was largely the result of a 13-million-ton (52-percent) increase in imports by the United Kingdom. In the Americas, a 7-million-ton (58-percent) increase in imports by the United States boosted the overall total for the region [**103**].

Increased imports of coal to the United Kingdom in 2001 were attributable to a combination of strong growth in electricity demand during the year, high natural gas prices, and limited availability of domestic coal supply [**104**]. In the United States the record-breaking level of coal imports was due to both heightened demand for low-sulfur coal by U.S. electricity producers to meet sulfur emission requirements and a tight domestic coal supply market for most of the year [**105**].

On the transportation side, ocean freight rates declined substantially in 2001, despite strong growth in international coal trade. Declining freight rates were attributable in part to a displacement of medium coal export hauls in the Asian market, originating from countries such as Australia and South Africa, with considerably shorter hauls out of China and Indonesia [**106**].

Relative to 2001, the year 2002 was marked by a much smaller gain in world coal trade (increasing by less than 2 percent), a continuation of low ocean freight rates through the first half of the year, and declining coal export prices through much of the year [**107**]. 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, including Australia, South Africa, and Russia [**108**].[19]

Between 1998 and 2001 coal exports from China expanded by a remarkable 178 percent, from 36 million tons in 1998 to 100 million tons in 2001. Preliminary data indicate that China exported 97 million tons of coal during 2002, maintaining its position as the second leading coal export country in the world, ahead of South Africa and Indonesia [**109**]. The United States, which was the second largest coal exporter in the world from 1984 through 1998, was surpassed by South Africa and Indonesia in 1999 and by China in 2000.

Recent actions by the Chinese government to encourage coal exports include an increase in coal export rebates and a reduction in the export handling fees charged by China's four official coal export agencies [**110**]. A recent forecast from the Chinese government places coal exports at 132 million tons by 2005 [**111**].

Asia

Despite setbacks that resulted from the region's financial crisis in 1998, Asia's demand for imported coal remains poised for additional increases over the forecast period, based on strong growth in electricity demand in the region. 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 24 percent of total world imports in 2025, slightly less than its 2001 share of 26 percent [**112**]. 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 via their annual price negotiations with major coal export suppliers (see box on page 91). Declining gradually over time, Japan's share of total Asian coal imports has fallen from 85 percent in 1980 to 60 percent in 1990 and to 48 percent in 2001.

In 2001, Japan produced slightly less than 4 million tons of coal for domestic consumption and imported 171 million tons [**113**]. The closure of Japan's last two underground mines, Ikeshima and Taiheiyo, in late 2001 and early 2002 leaves virtually all of Japan's coal requirements to be met by imports [**114**].

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 Asian imports. 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 (1.8 billion tons) in coal demand. In addition, coal imports by Malaysia and the Philippines are also projected to rise substantially over the forecast period, primarily to satisfy demand at new coal-fired power plants. Diversification of fuel

[19]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.

Japanese Benchmark Coal Prices and the Asian Coal Market

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

Japan's influence has declined somewhat over the past several years, however, and the benchmark pricing system that was so influential in setting contract prices for Japan's steel mills was revised substantially in 1996. The revisions reflected a move away from a system which, in effect, averaged coal prices (with minor adjustments for quality) to a regime with a broad spectrum of prices, where high-quality coking coals received a substantial premium relative to lower quality coals.[b]

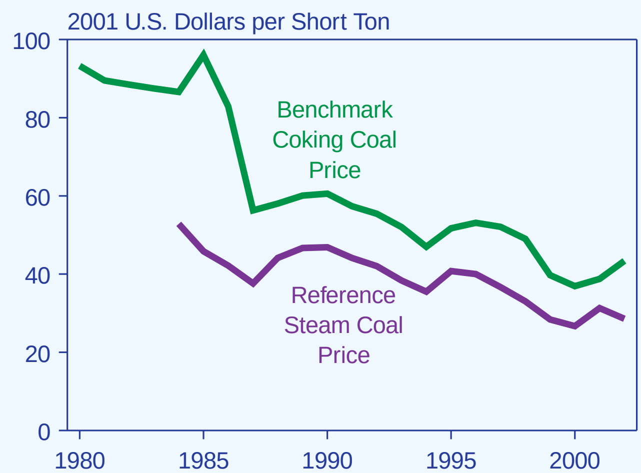
Changes have also occurred in the annual price negotiations between Japanese electric utilities and Australian steam coal suppliers. Traditionally, Japanese utilities have met most of their coal requirements through the use of long-term contracts that are subject to annual price reviews. Annual negotiations to adjust the price, quantity, and quality components of long-term coal contracts with foreign suppliers evolved during the oil price shocks of the 1970s and remain a key feature of this market.[c] The Japanese power utilities would approach the Australian suppliers as a single entity, with one or two individual utilities appointed by the others as the lead or "champion" negotiators. The annual negotiations established what was referred to as a "benchmark" or "reference" price for Australian thermal coal (see figure), a price that was more or less accepted by all the individual Japanese utilities and Australian coal suppliers and served as the basis for setting contract prices in other Asian countries.[d]

While a "reference" contract price continues to be negotiated and widely noted in industry news and publications, several factors have contributed toward a recent decline in the share of total Australian imports by Japan's electric companies that is priced at this level. One key factor has been a trend by Japanese electric utilities to satisfy increasing amounts of their annual coal requirements with spot-market purchases. Rising from approximately 5 percent of total coal purchases in 1995, spot purchases of coal by Japanese electric utilities have grown considerably in recent years, accounting for an estimated 30-percent share of total import requirements in 2001.[e]

A second factor contributing to the reduced importance of the "reference" price for thermal coal has been the ongoing liberalization of the Japanese electricity market. In essence, increasing competition is placing cost-cutting pressure on Japan's electricity producers, making each individual utility less inclined to accept a

(continued on page 92)

Japanese Benchmark/Reference Coal Prices, 1980-2002



Sources: **Coking Coal:** 1980-2001: International Energy Agency, *Coal Information 2002* (Paris, France, September 2002), Table 2.11; 2002: A. Tilbury, "Coal Giants Fire Up for Price Talks," *The Age* (January 13, 2003). **Steam Coal:** International Energy Agency, *Coal Information 2002* (Paris, France, September 2002), Table 2.6. **GDP Deflators:** U.S. Department of Commerce, Bureau of Economic Analysis.

[a]International Energy Agency, *International Coal Trade: The Evolution of a Global Market* (Paris, France, January 1998).

[b]B. Jacques, "High Turnover, Low Returns," *Financial Times* (July 8, 1996), p. 1.

[c]Productivity Commission, *The Australian Black Coal Industry, Inquiry Report, Volume 1: Report* (Canberra, Australia, July 3, 1998), Appendix D, web site www.pc.gov.au; "Japan Power / Coal: Less Need for Chubu Electric as Benchmark," *DowJones Newswires* (December 11, 1996).

[d]Productivity Commission, *The Australian Black Coal Industry, Inquiry Report, Volume 1: Report* (Canberra, Australia, July 3, 1998), Appendix D, web site www.pc.gov.au; "J-Power, Kosep and Taipower Want to Keep a Reference Price," *Platts International Coal Report*, No. 589 (November 25, 2002), p. 8.

[e]"Japan's Utilities May Boost Share of Spot Market Steam Coal Imports," *Platts International Coal Report*, Vol. 17, No. 5 (February 12, 1996), p. 2; "Australian Spot Steam Coal Prices Out of Sync With Atlantic Market, Fall Likely Near Term," *Platts International Coal Report*, No. 555 (April 1, 2002), p. 1.

supply for electricity generation is the key factor underlying plans for additional coal-fired generating capacity in these countries. In Thailand, strong environmental opposition to coal has appeared to have prevailed over the desire for diversification of fuel supply leading to the government's cancellation of two large coal-fired generation projects [***115***]. This leaves only one planned coal plant for Thailand, the 1,364-megawatt Rayong plant being built by BLCP Power (a consortium of energy companies), which is scheduled to come on-line in late 2006 [***116***].

During the 1980s, Australia became the leading coal exporter in the world, primarily by meeting increased demand for steam coal in Asia. Considerable growth in exports of coking coal also occurred, however, as

Japanese Benchmark Coal Prices and the Asian Coal Market (Continued)

price negotiated by one of the other utilities. As a result, Japanese power utilities have largely discontinued collective negotiations in favor of individual bargaining with suppliers and increasing reliance on spot-market purchases.[f]

A third factor contributing to the reduced importance of Japan's "reference" coal price in Asia, and to an overall reduction in electricity fuel costs as well, is an increasing ability or willingness by plants in the region to purchase a wider range of coals, reducing their dependence on any one specific supply region or mine.[g] This trend not only is the result of newer power plants being technically capable of burning a wider range of coals than older plants in the region but also is attributable to a greater flexibility in fuel procurement by operators of older plants. Industry experts point to South Korea's stock of relatively modern plants as a key factor underlying that country's increasing use of Chinese coals, whose higher calcium content, for example, can cause problems at older coal plants.[h] Japanese utilities, however, continue to adhere to somewhat stricter coal quality requirements than other Asian utilities, citing factors such as their country's extreme focus on reliability of electricity supply and slagging and fouling problems encountered at some Japanese plants in the past with the use of certain types of Chinese coal.[i]

The shift to more competitive coal markets in Asia implies that coal producers in Australia and other exporting countries will be under increased pressure to reduce mining costs in order to maintain current rates of return. It also means that more distant suppliers, such as the United States and Canada, will find it increasingly difficult to increase or maintain export sales to the region.

On the supply side, however, there has been a movement toward increasing consolidation, with several coal-producing companies garnering an increasing share of total world export capacity. Industry consolidation has the potential to give coal export suppliers greater pricing power, based on their ability to control the quantity of coal available for export, which, in turn, diminishes to some extent the ability of coal importers to negotiate lower prices. During 2001, nearly 40 percent of international steam coal shipments originated from mines owned by just four companies: Anglo American, Glencore/Xstrata, BHP Billiton, and Rio Tinto.[j] By major exporting country in 2001, those four companies, taken as a whole, controlled an estimated 70, 60, and 45 percent of the steam coal exports originating from South Africa, Colombia, and Australia, respectively.

The ability of a group of major coal export suppliers to exert significant control over international export prices remains to be seen. Factors working against such an outcome are that coal resources are plentiful and widely distributed throughout the world, and only a small proportion of the world's total annual production is traded.[k] Thus, while short-term increases in coal export prices are plausible as a result of limited supply, in the medium to long term the capability to expand existing mines and to bring new low-cost mines on line in the world's major coal-exporting countries, combined with continuing improvements in coal mining productivity, should continue to exert downward pressure on coal export prices.

[f]"Reference Price Lives On," McCloskey's Coal Report, No. 50 (December 13, 2002), pp. 1-3; "Smaller Japanese Utilities Lower Contract Prices Pushing Asian Market Down," *Platts International Coal Report*, No. 574 (August 12, 2002), p. 1; "Chinese Suppliers Finally Get Invited to Japan Spot Tenders," *Platts International Coal Report*, No. 566 (June 17, 2002), p. 4; Productivity Commission, *The Australian Black Coal Industry, Inquiry Report, Volume 1: Report* (Canberra, Australia, July 3, 1998), Appendix D, web site www.pc.gov.au.

[g]"Cheaper Coal Could Give South Korea a Competitive Edge," *Platts International Coal Report*, No. 581 (September 30, 2002), p. 3; "Japanese Utility to Expand Coal Specs for More Flexible Buying," *Platts International Coal Report*, No. 571 (July 22, 2002), p. 11; "Japan's EPDC to Burn Trial Coal in JFY 2002, But Imports Will Decline," *Platts International Coal Report*, No. 544 (January 14, 2002), p. 6.

[h]A. Roberts, "Price Volatility Persists," *Petroleum Economist* (October 2, 2002).

[i]"Cheaper Coal Could Give South Korea a Competitive Edge," *Platts International Coal Report*, No. 581 (September 30, 2002), p. 3; "Some Utilities Ready For Open Trading With China," *Platts International Coal Report*, No. 569 (July 8, 2002), p. 12.

[j]A. Roberts, "Price Volatility Persists," *Petroleum Economist* (October 2, 2002).

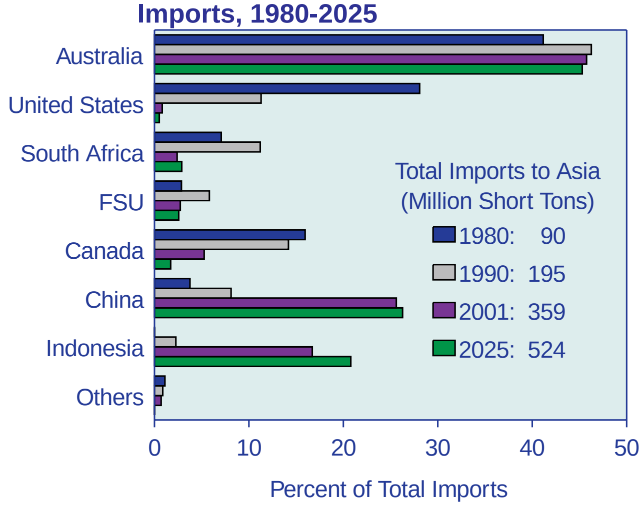
[k]International Energy Agency, *International Coal Trade: The Evolution of a Global Market* (Paris, France, January 1998), p. 75.

countries such as Japan began using some of Australia's semi-soft or weak coking coals in their coke oven blends. As a result, imports of hard coking coals from other countries, including the United States, were displaced. Australia's share of total world coal trade, which increased from 17 percent in 1980 to 33 percent in 2001, is projected to increase slightly over the forecast period, reaching 35 percent by 2025 [*117*]. Australia should continue as the major exporter to Asia, with its share of the region's total coal import demand projected to remain at or near its current level of 46 percent (Figure 64).

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 [*118*]. Factors contributing to China's expanding coal export position in Asia include: (1) the recent completion of projects and further commitments by the Chinese government to improve rail links to ports and to construct new coal export facilities; (2) continuing support for China's coal export industry through state subsidies; (3) aggressive pricing of coal exports, emphasizing market share rather than profits; and (4) the relatively short transport distances from China's coal-exporting ports to Asia's major coal-importing countries, ensuring low shipping costs [*119*]. Over the forecast period, China is expected to increase slightly its share of the region's overall coal import market.

The United States, once a major supplier of coal to Asia, is currently only a minor participant the Asian market. As shown in Figure 64, the U.S. share of total coal imports by Asia has declined from 28 percent in 1980 to less than 1 percent in 2001. An additional setback in U.S. coal exports to this region occurred during 2002 as

Figure 64. Foreign Supplier Shares of Asian Coal Imports, 1980-2025



Sources: **1985-2001:** SSY Consultancy and Research, Ltd., *SSY's Coal Trade Forecast*, Vol. 11, No. 4 (London, UK, September 2002). **2025:** Energy Information Administration, National Energy Modeling System run IEO2003.D033103A (March 2003).

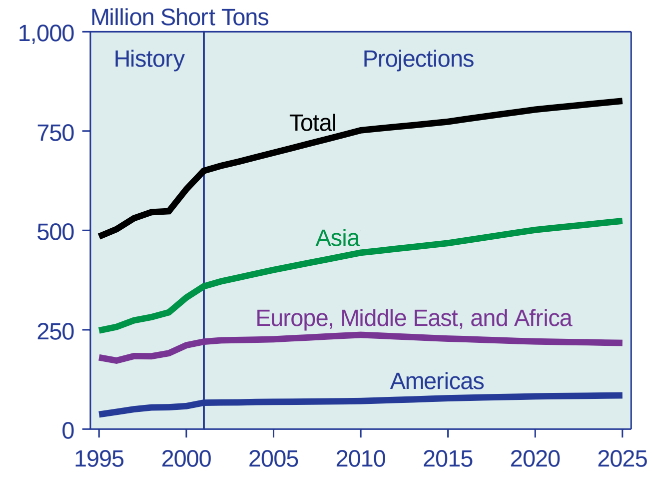
Alaska's Usibelli coal mine was unable to renegotiate a long-term sales contract with Korea East-West Power Company, Ltd [*120*] (formerly part of the Korea Electric Power Company). Beginning with shipments in 1984, the Usibelli mine typically exported between 700,000 and 800,000 tons of subbituminous coal annually to South Korea for use at the Honam coal-fired power station [*121*]. Usibelli Coal has since submitted a new contract proposal to Korea East-West Power Company and is looking at other potential markets for its product, such as coal plants that may eventually be built on the west coasts of the United States or Mexico [*122*].

Europe, Middle East, and Africa

Coal imports to Europe, the Middle East, and Africa taken as a whole are projected to fall by approximately 2 percent over the forecast period (Figure 65). Projected declines in overall imports to the countries of Western Europe are offset by small increases projected for Turkey, Romania, Morocco, and Israel.

In Western Europe, strong environmental lobbies 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, increasing import requirements for coal coke but reducing imports of coking coal.

Figure 65. 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. 11, No. 4 (London, UK, September 2002); International Energy Agency, *Coal Information 2001* (Paris, France, September 2001), and previous issues; Energy Information Administration, *Quarterly Coal Report*, DOE/EIA-0121(2001/4Q) (Washington, DC, May 2002), and previous issues. **Projections:** Energy Information Administration, National Energy Modeling System run IEO2003. D033103A (March 2003).

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 gap in energy supply left by the continuing declines in the region's indigenous coal production.

In 2001, the leading suppliers of imported coal to Europe were South Africa (29 percent), Australia (19 percent), South America (13 percent), and the United States (10 percent). 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 expected gains in South America's foothold in Europe, South Africa is projected to maintain its position as the leading supplier of coal to Europe. Currently, plans call for an 11-million-ton expansion in South Africa's Richards Bay Coal Terminal, increasing the facility's annual throughput capacity to 90 million tons [***123***]. (All Africa, 11/8/02 and 12/13/02). The estimated completion date for this project is sometime in 2005.

The Americas

Compared with European and Asian coal markets, imports of coal to North and South America are relatively small, amounting to only 66 million tons in 2001 (see Table 19). Canada imported 36 percent of the 2001 total, followed by the United States (30 percent) and Brazil (25 percent) [***124***]. Most (77 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 [***125***].

Over the *IEO2003* forecast period, coal imports to the Americas are projected to increase by 18 million tons, with most of the additional tonnage going to Mexico, the United States, and Brazil. Coal imports to the United States are projected to increase from 20 million tons in 2001 to 28 million tons by 2025 [***126***]. Coal-fired power plants located along the eastern seaboard and in the southeastern part of the country are expected to take most of the additional import tonnage projected over the forecast period, primarily as a substitute for higher priced coal from domestic producers. 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 over the next few years as six nuclear generating units at the Pickering and Bruce plants gradually are returned to service [***127***]. While generation from some of these units is crucial for averting expected near-term shortages in the Province's electricity supply [***128***], the return to service of all six units over the next few years should ultimately displace some of the generation from Ontario's coal-fired power plants. Coal plants in Nova Scotia, however, are expected to increase their take of imports after the closure of Canada's Phalen and Prince underground mines in 2000 and 2001 [***129***]. During 2000, Nova Scotia Power purchased 0.8 million tons of domestic coal (primarily from the Prince mine) and 2.3 million tons of imports [***130***].

Coking Coal

Historically, coking coal has dominated world coal trade, but its share has steadily declined, from 55 percent in 1980 to 32 percent in 2001 [***131***]. In the forecast, its share of world coal trade continues to shrink, to 27 percent by 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 decline in coking coal imports in the industrialized countries are continuing increases in steel production from electric arc furnaces (which do not use coal coke as an input) and technological improvements at blast furnaces, including greater use of pulverized coal injection equipment and higher average injection rates per ton of hot metal produced. Each ton of pulverized coal (categorized as steam coal) used in steel production displaces approximately one ton of coking coal [***132***].[20] In 2000, the direct use of pulverized coal at blast furnaces accounted for 16 percent and 14 percent of the coal consumed for steelmaking in the European Union and Japan, respectively [***133***].

[20] Approximately 1.4 tons of coking coal are 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.

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Nuclear Power

Nuclear power is projected to represent a shrinking share of the world's electricity consumption from 2001 through 2025, despite a net increase in world nuclear capacity as a result of new construction and life extensions.

In the *International Energy Outlook 2003* (*IEO2003*) reference case, the nuclear share of the world's total electricity supply is projected to fall from 19 percent in 2001 to 12 percent by 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.

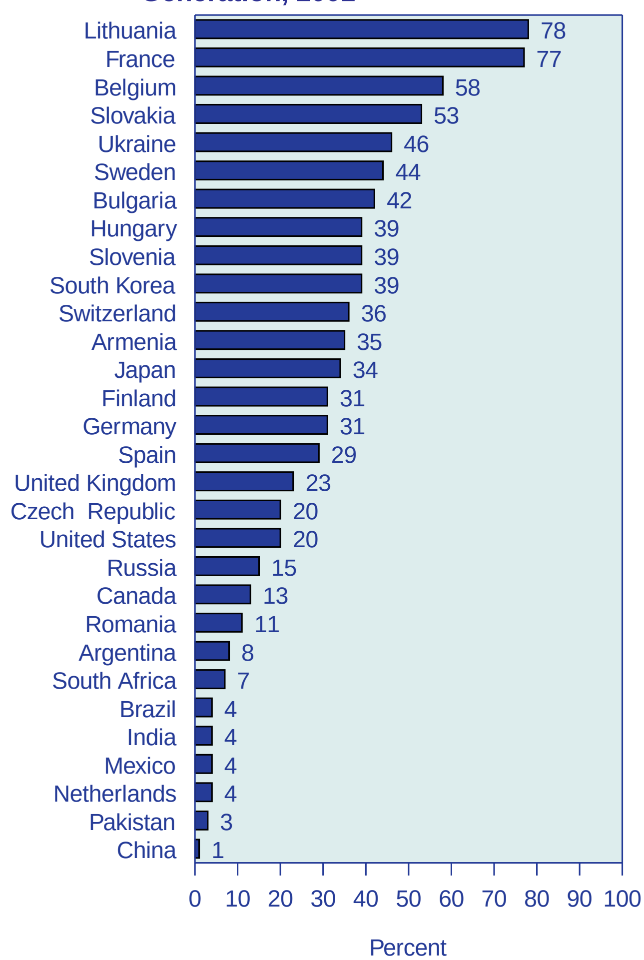
For the most part, and under most economic assumptions, nuclear power is a relatively expensive option for electricity generation when compared with natural gas or coal, particularly for nations with access to inexpensive sources of coal and natural gas. In addition, there is strong public sentiment 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 other countries where for new nuclear construction capital costs can be relatively low, discount rates low, and construction times potentially short, and 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 2001 (Figure 66). In absolute terms the world's total nuclear power capacity is projected to increase from 353 gigawatts in 2001 to 366 gigawatts in 2025 in the reference case (Table 20). Most nuclear capacity additions are expected to be in Asia, where China, India, Japan, and South Korea are projected to add a combined total of approximately 45 gigawatts of nuclear capacity between 2001 and 2025, while the rest of the world sheds some 32 gigawatts of existing capacity. In addition, life extensions, higher capacity factors, and capacity uprates are expected to offset some of the capacity lost through plant retirements in other parts of the world. Life extension and higher capacity factors will play a major role in sustaining the U.S. nuclear industry throughout the forecast period. Russia also has an ambitious life extension program. 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 2002 there were 441 nuclear power reactors in operation around the world (Figure 67). Another 33 nuclear power plants were under construction (Figure 68). Six new nuclear power plants began operation in 2002—four in China and one each in South Korea and the Czech Republic [***1***].

Nuclear power projections are subject to considerable uncertainty, both economic and political. The *IEO2003* high and low nuclear growth cases illustrate a range of possible outcomes, based on more optimistic and more pessimistic assumptions than in the reference case. On

Figure 66. Nuclear Shares of National Electricity Generation, 2001



Source: International Atomic Energy Agency, Reference Data Series 2, "Power Reactor Information System," web site www.iaea.org/ programmes/a2/.

Table 20. Historical and Projected Operable Nuclear Capacities by Region, 2001-2025
(Net Gigawatts)

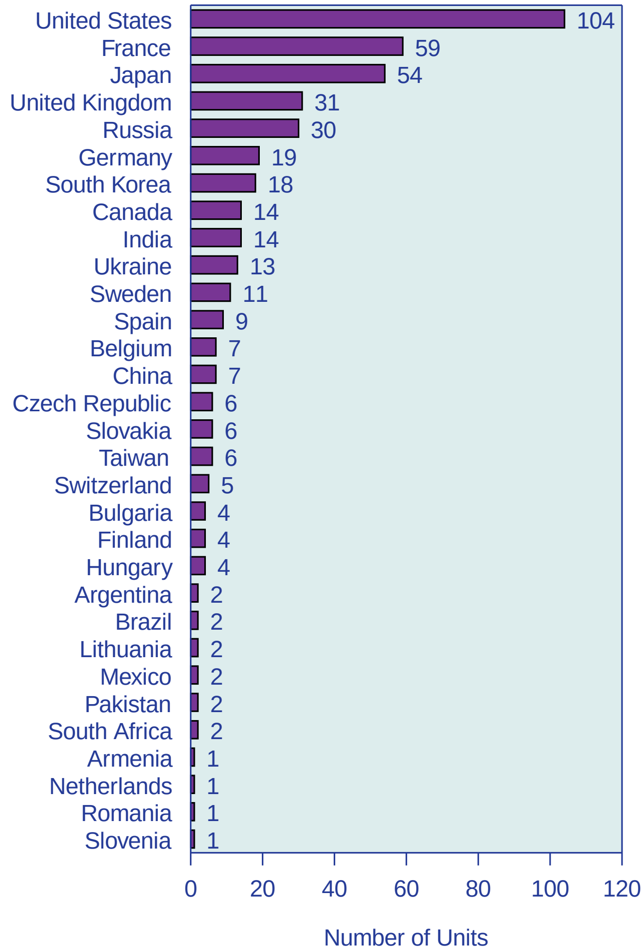
Region	2001[a]	2005	2010	2015	2020	2025
			Reference Case			
Industrialized	**278.7**	**283.9**	**290.7**	**288.5**	**279.4**	**260.9**
United States	98.2	100.2	99.3	99.5	99.6	99.6
Other North America	11.4	14.6	15.9	15.9	15.9	13.0
Japan	43.2	45.0	49.4	52.2	52.2	51.9
France	63.1	63.5	66.6	66.6	66.6	64.7
United Kingdom	12.5	11.0	11.1	7.0	6.0	5.4
Other Western Europe	50.3	49.7	48.4	47.3	39.1	26.3
EE/FSU	**46.3**	**46.6**	**46.4**	**45.0**	**39.9**	**34.7**
Eastern Europe	11.6	11.8	10.7	10.7	11.3	11.3
Russia	20.8	22.0	23.5	22.5	16.7	14.5
Ukraine	11.2	11.3	11.9	11.9	11.9	8.9
Other FSU	2.7	1.6	0.4	0.0	0.0	0.0
Developing	**27.6**	**37.9**	**44.7**	**59.6**	**63.2**	**70.4**
China	2.2	7.6	8.6	16.6	16.6	19.6
South Korea	13.0	16.9	18.0	20.9	23.6	27.6
Other	12.4	13.3	18.1	22.2	23.1	23.2
Total World	**352.6**	**368.4**	**381.8**	**393.1**	**382.5**	**366.0**
			Low Growth Case			
Industrialized	**278.7**	**281.1**	**278.9**	**259.9**	**224.8**	**185.2**
United States	98.2	100.2	99.3	99.5	99.6	99.6
Other North America	11.4	14.6	15.2	12.3	10.7	9.8
Japan	43.2	43.9	49.4	48.6	41.6	35.8
France	63.1	63.5	66.6	64.7	54.3	33.2
United Kingdom	12.5	11.0	7.0	3.6	1.3	1.3
Other Western Europe	50.3	47.9	41.4	31.2	17.3	6.5
EE/FSU	**46.3**	**45.0**	**43.0**	**36.4**	**30.1**	**17.3**
Eastern Europe	11.6	11.0	10.7	10.7	11.3	8.4
Russia	20.8	21.6	22.5	16.7	12.8	7.9
Ukraine	11.2	11.3	9.8	9.1	6.0	1.0
Other FSU	2.7	1.2	0.0	0.0	0.0	0.0
Developing	**27.6**	**35.6**	**41.6**	**48.3**	**52.1**	**50.6**
China	2.2	6.6	8.6	9.6	12.6	12.3
South Korea	13.0	16.0	17.1	19.9	20.2	21.3
Other	12.4	13.0	16.0	18.7	19.2	17.0
Total World	**352.6**	**361.7**	**363.5**	**344.6**	**306.9**	**253.1**
			High Growth Case			
Industrialized	**278.7**	**288.1**	**298.3**	**314.5**	**335.8**	**351.6**
United States	98.2	100.2	99.3	99.5	99.6	99.6
Other North America	11.4	14.6	15.9	16.6	18.3	20.0
Japan	43.2	47.0	51.6	60.0	70.4	73.7
France	63.1	63.7	66.6	69.5	72.4	75.3
United Kingdom	12.5	11.9	11.1	14.0	16.2	17.0
Other Western Europe	50.3	50.8	53.8	55.0	58.9	66.0
EE/FSU	**46.3**	**49.6**	**56.7**	**64.9**	**78.2**	**96.3**
Eastern Europe	11.6	12.6	12.6	16.2	19.7	25.7
Russia	20.8	22.9	28.8	33.6	39.9	43.1
Ukraine	11.2	11.3	13.8	13.8	15.7	17.7
Other FSU	2.7	2.7	1.6	1.4	2.9	9.9
Developing	**27.6**	**39.4**	**56.0**	**71.6**	**97.6**	**119.0**
China	2.2	8.6	11.7	17.7	20.7	22.7
South Korea	13.0	16.9	20.5	24.9	30.3	34.4
Other	12.4	13.9	23.8	29.0	46.6	62.6
Total World	**352.6**	**377.1**	**411.0**	**451.0**	**511.5**	**566.9**

[a]Status as of December 31, 2001. Data are preliminary and may not match other EIA sources.

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

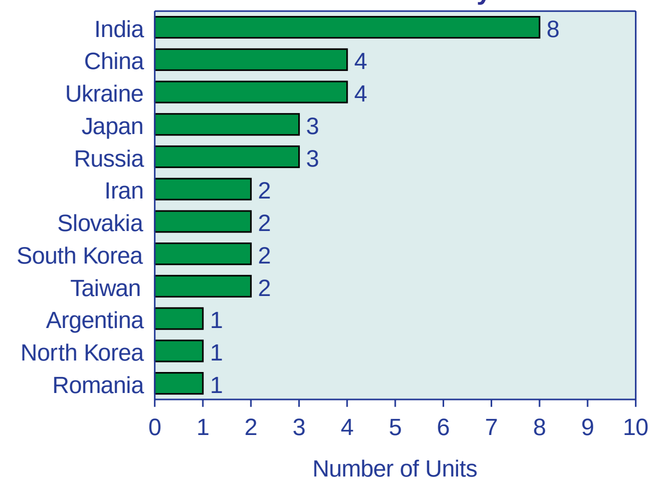
Sources: **United States:** Energy Information Administration, *Annual Energy Outlook 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003). **Foreign:** Based on detailed assessments of country-specific nuclear power programs.

Figure 67. Operating Nuclear Power Plants Worldwide as of February 2003



Source: International Atomic Energy Agency, Reference Data Series 2, "Power Reactor Information System," web site www.iaea.org/ programmes/a2/ (February 15, 2003).

Figure 68. Nuclear Power Reactors Under Construction as of January 2003



Source: International Atomic Energy Agency, Reference Data Series 2, "Power Reactor Information System," web site www.iaea.org/ programmes/a2/ (January 1, 2003).

the optimistic side, for example, emerging technologies could change the economics and perceived safety of nuclear power plants, as well as public sentiment about radioactive waste disposal and nuclear weapons proliferation. In the high nuclear growth case, world nuclear capacity is projected to grow from 353 gigawatts in 2001 to 567 gigawatts in 2025 (Table 20).

On the pessimistic side, whatever public support for nuclear power is currently in evidence could be eroded quickly if a serious nuclear mishap occurred anywhere in the world; expected technology breakthroughs might not materialize; and future delays or cost overruns on nuclear power construction projects could adversely affect economics. In fact, there have been no new orders for nuclear power plants since 1978 in the United States and none since 1993 in the European member countries of the Organization for Economic Cooperation and Development (OECD). Nuclear power development generally depends on government support or sanction, and political developments can bring into power political parties that are opposed to the nuclear option, as has happened in Western Europe in recent years. In the low nuclear growth case, world nuclear capacity is projected to shrink from 353 gigawatts in 2001 to 253 gigawatts in 2025 (Table 20). The low nuclear growth case does, however, include new builds in other regions, specifically Asia. The following paragraphs discuss in more detail some of the uncertainties that could affect the future of nuclear power around the world.

The nuclear accidents at Three Mile Island in the United States in 1979 and at Chernobyl in the Soviet Union in 1986 did serious damage to nuclear prospects during the 1980s and 1990s. More recently, however, significant improvements in operating and safety performance have improved the image of nuclear power and its future global prospects. For instance, the average world nuclear power plant availability factor has improved from 73 percent in 1990 to 83 percent in 2001 [***2***], and average U.S. capacity factors have improved from 71 percent in 1992 to 89 percent in 2001 [***3***]. Greater capacity utilization has allowed the U.S. nuclear power industry to increase its net generation by 19 percent between 1991 and 2001,[21] despite a nearly 2-percent decrease in operable nuclear capacity over the same period [***4***]. At the same time, both overseas and in the United States, safety measures have shown considerable improvement. Nuclear power has also become a more desirable option from the perspective of meeting the carbon dioxide emission reduction targets of the Kyoto Protocol.

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,

[21]Measured as the net summer capability of operating units.

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 have 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. Moreover, "committed" can be an ambiguous term, given that political parties with different views on nuclear power are periodically voted in or out of national office.

In large part, government support for nuclear power has waxed and waned with the changing of governing regimes, depending on whether the nation's ruling party is liberal or conservative. In recent years public officials and industry representatives from various nations have called for a reevaluation of nuclear power. For example, France, the Netherlands, Italy, and the United States have recently elected conservative governments more favorably inclined to nuclear options. In 2001, the interim head of the Italian environmental protection agency stated that the country should review its nuclear energy options and consider the potential national benefits of new generation technologies [*5*]. In the Netherlands, representatives of the ruling coalition have proposed construction of a new plant [*6*]. In the United States, the Bush Administration's energy plan calls for the expansion of nuclear energy "as a major component of our national energy policy." Current U.S. energy goals include an intended new build by the end of the current decade. Further, the Bush Administration budget proposal for 2003 included a provision to increase spending on nuclear technology research to $46.5 million from $12 million in 2002 [*7*].

In contrast, liberal governments in Sweden and Germany have committed both nations to the early retirement of their nuclear power sectors, and their recent successes at the ballot box (in September 2002) may lower the odds of reviving nuclear power programs in both countries. Since June 2000, Germany has been committed to the shutdown of its nuclear power industry by the mid-2020s, or after German reactors have been operational for an average of 32 years. Germany's current Social Democratic chancellor, Gerhard Schröder, with the strong backing of political allies in the environmentalist Green Party, negotiated the terms of the nuclear phaseout with Germany's electricity industry. It remains unclear, however, whether the goals will be met. Shortly after the September election, the German nuclear supply industry showed some hesitancy about meeting the agreed target date. In October, Energie Baden Warttemberg AG (EnBW) applied for government permission to delay the scheduled closure of its Obrigheim nuclear power station for 5 years [*8*]; and the Chief Executive Officer of E.ON, Germany's second largest electricity company, has called for the retention of nuclear power [*9*].

If the closely decided German election in September 2002 had gone the other way, Germany might well have reversed its commitment to a nuclear shutdown. Schröder's opponent, the Christian Democratic leader Edmund Stoiber, and his Free Democrat allies had adopted a platform that included a more accommodating view of nuclear power. A Stoiber government might have delayed, tabled, or reversed the ambitious nuclear shutdown plan. In Lithuania, not long after the previous government had committed to a scheduled shutdown of its existing nuclear power industry, the newly elected president, who assumed office in February 2003, stated that Lithuania must retain its nuclear power program "for definite" [*10*].

Political and economic considerations clearly can affect national plans for moving away from nuclear power. For instance, Sweden is committed to closing down its nuclear power industry entirely by the time the youngest of its nuclear power reactors reaches the end its expected lifespan—which was generally assumed to be around the year 2010—but the first two plant closures in the nuclear phaseout plan were repeatedly delayed [*11*]. Barsebäck 1, originally scheduled for shutdown in July 1998, continued operating until November 1999; and Barsebäck 2, originally scheduled for closure in 2001, remains in operation. Only 2 months after the Swedish elections in November 2002, two reports commissioned by the government pointed to the difficulties that might arise from closing Barsebäck 2 on schedule [12]. In March 2003, the Swedish government admitted that the necessary conditions for closing Barsebäck 2 (i.e., finding an alternative source of power) could not be met.

Sweden's goal of phasing out its nuclear generation and simultaneously attempting to meet its commitment to greenhouse gas reductions following its ratification of the Kyoto Protocol in March 2002 poses a particular dilemma for this resource-intensive nation [13]. Energy-intensive industries, such as forest products and iron and steel, contribute a sizable sum to Sweden's gross domestic product (GDP) and exports, and it has been estimated that 5 percent of the nation's GDP could be lost when nuclear power is phased out entirely. Combining a nuclear phaseout with climate change commitments could cost Sweden roughly one-third of its annual GDP [14].

Another factor being weighed by European nations in deciding whether to abandon, continue, or expand their nuclear power programs is the influence of the multilateral European Union (EU). Although the EU does not set the energy policies of its members, its voice can influence the debate. European Commission Vice President (and also Transport and Energy Commissioner) Loyola de Palacio has stated that it would be "irresponsible" for countries to ignore nuclear power [15], and in mid-2002 the Commission published a report that called for keeping the nuclear option open [16].

The political divisions between pro- and anti-nuclear advocates is particularly sharp in Taiwan. When the Democratic Progressive Party of Taiwan was elected to power in March 2000, President Chen Shui-bian promised a phaseout of nuclear power and an emphasis on liquefied natural gas (LNG) as a future source of electricity. Before the election, the Kuomintang (KMT) party had ruled Taiwan since the fall of Nationalist China in 1949. A multi-party democracy emerged in Taiwan during the mid-1980s, along with a strong anti-nuclear movement. In October 2000, in pursuit of his goal of making Taiwan nuclear free, President Chen announced a decision to cancel construction of the Lungmen nuclear power station after the project had been one-third completed, which led to a major row with the more conservative parliament. Opposition parties, led by the KMT, control the parliament and were strongly opposed to the cancellation of Lungmen 1 and 2, viewing such a step as unconstitutional. In February 2001, President Chen reached an agreement with the parliamentary opposition to complete Lungmen but also to continue the pursuit of a non-nuclear Taiwan.

Finally, the on-again off-again history of Labor Party support for a nuclear phaseout in the United Kingdom suggests that opposing views on nuclear policy may exist not only across parties but also within a single party and, perhaps, within a single politician over time. In 1986, the Labor Party voted to phase out the nation's nuclear power plants gradually over a period of decades [17]. More recently, in 1997, its general election manifesto opposed adding to the country's nuclear power industry. Since the Labor Party's Prime Minister Tony Blair came into office in 2001, however, several energy policy statements from the government have suggested that the Prime Minister's office may have significantly softened its previous opposition to nuclear power. There has even been speculation that the Blair government could eventually come out in support of new builds. Then, in January 2003, the government appeared to reverse course again, when the allegedly pro-nuclear energy policy minister, Brian Wilson, called for a 5-year moratorium on construction of new nuclear power capacity [18].

Regional Developments

Asia

In Asia, nuclear power plants are currently under construction in China, South Korea, India, Taiwan, and Japan. In contrast to most of the rest of the world, developing Asia, in particular, still supports a buoyant nuclear power plant construction industry. For the developing countries of Asia (excluding Japan, which is part of the industrialized Asia country grouping), the *IEO2003* reference case projects a 17-percent share of the world's total nuclear power capacity in 2025, up from 7 percent in 2001.

China

In 2001, China had only three nuclear power units in operation: Guangdong 1 and 2 (944 megawatts each) and Qinshan 1 (279 megawatts). Four new units were opened in 2002, adding a total of 3,151 megawatts of nuclear capacity: Lingao 1 and 2 (938 megawatts each), Qinshan 2 unit 1 (610 megawatts), and Qinshan 3 unit 1 (665 megawatts). In the *IEO2003* reference case, China's nuclear capacity is projected to grow from 2,167 megawatts in 2001 to 19,593 megawatts in 2025—the largest increase projected for any country in the world.

China has been attempting to develop an indigenous nuclear technology base for some time. Thus far, China's nuclear power program has used a variety of nuclear technologies, some imported and some domestic. A goal of the program, as stated by the chairman of China's Atomic Energy Authority, is to "attain independence in the design, manufacture and operation of large nuclear power units on the basis of learning [from the] advanced experience of other countries" [19]. China's first reactors, Guangdong 1 and 2, were designed by French Framatome ANP and came on line in 1993 and 1994. Qinshan 1, which came on line in 1991, was China's first domestically designed unit, and its design was scaled up for Qinshan 2 units 1 and 2 [***20***]. Qinshan 3 unit 1 is China's first reactor based on Canadian Candu technology. The two Lingao reactors that came on line in 2002 use French technology supplied by Framatome ANP.

South Korea

South Korea's nuclear power capacity is projected to grow from 12,990 megawatts in 2001 to 27,607 megawatts in 2025 in the reference case. Two 960-megawatt units, Ulchin 5 and 6, are currently under construction [***21***]. The country has pursued an aggressive nuclear power program since the late 1970s and has announced plans to build 10 new nuclear power reactors by 2025 (see box below).

Japan

Japan is one of the few advanced industrialized nations projected to build additional reactors over the 2001-2025 time frame. Japan—the world's third largest producer of nuclear power, after the United States and France—completed its fifty-third nuclear reactor in 2001, the 798-megawatt Onagawa 3. In the *IEO2003* reference case, Japan's nuclear power capacity is projected to grow from 43,245 megawatts in 2001 to 51,899 megawatts in 2025.

Recent events could stall Japan's effort to expand its nuclear power industry. A scandal of major proportions emerged in August 2002, when it was disclosed that Japan's largest nuclear power company, Tokyo Electric

The South Korean Standard Nuclear Plant Design

Nuclear power currently provides South Korea with 39 percent of its electricity supply. Because it lacks indigenous energy resources, South Korea was eager to develop nuclear power for its electricity sector and began a nuclear power program with the assistance of the United States in the 1950s. With U.S. aid, South Korea constructed a nuclear research reactor that was completed in 1962.

In the early 1970s, South Korea was virtually entirely reliant on oil for electricity generation, a reliance that left the nation particularly vulnerable to the first oil price shock in 1973. In the early 1970s, South Korea's nuclear power program went into full swing, and its first nuclear power plant, Kori 1, was completed in 1978. Between 1983 and 1989, eight new plants were added, and by 1989 nuclear accounted for 51 percent of South Korea's electricity generation.[a]

The purpose of South Korea's nuclear power program was in part to encourage self-reliance in nuclear power plant construction, operation, and maintenance. It was also to achieve a high degree of standardization in order to reduce costs and make operations easier. South Korea (along with China and India) is one of a number of developing nations attempting to develop indigenous nuclear power plant designs. In 1987, ABB Combustion Engineering and the Korean nuclear power industry agreed on a 10-year program (which was extended for another 10 years in 1997) aimed at transferring nuclear technology to the Korean nuclear power industry.[b]

South Korea completed its tenth and eleventh nuclear power units when Yonggwang units 3 and 4 came on line in 1995 and 1996. Both of the 960-megawatt units were based on ABB Combustion Engineering's System 80 design, in collaboration with the Korea Power Engineering Company (KOPEC). KOPEC's role grew with the construction of subsequent units. Yonggwang units 5 and 6, completed in 2002 and 2003, represent the culmination of the South Korean standard nuclear plant (KSNP) design.

The KSNP program began in 1984 as part of the government's effort to increase South Korea's technological self-reliance in nuclear energy. The KSNP was developed from incremental design improvements, which built on the safety and reliability of earlier proven designs. The Ulchin 3 and 4 units in the North Kyungsang Province of South Korea, completed in 1998 and 1999, were the first KSNPs. Their design was in turn derived from the Yonggwang 3 and 4 power plants, which were modeled on the reactors at the Palo Verde nuclear generating station in the United States.[c] The basis for all these plants is ABB's System 80 design.

The next step in South Korea's nuclear power program is the development of the advanced Korea Next Generation Reactor (KNGR). In 1992, South Korea began developing designs for a standard Advanced Power Reactor 1400 (APR1400), with a goal of design certification occurring by the end of 2002.[d]

[a]Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219 (Washington, DC, various issues), web site www.eia.doe.gov/iea/.
[b]A. Matzie and K.I. Han, "The Evolutionary Development of Advanced Reactors," in *The Uranium Institute's Twenty Third Annual International Symposium 1998*, web site www.world-nuclear.org/sym/1998/matzie.htm.
[c]Korea Institute of Nuclear Energy, "Korea Power Program," web site www.kins.re.kr/eng/databank_7.html.
[d]E.S. Young, "RIC 2001 Recent Safety Issues and Perspectives in Korea Session TH3," Korea Institute of Nuclear Safety (March 15, 2001).

Power Co. (Tepco), had filed falsified inspection documents for 13 reactors [22]. The documents concealed from government regulators knowledge about cracks in structures holding nuclear fuel in place in reactor cores at several Tepco power plants. As a result of the disclosures, several senior Tepco executives, including the company's president, were forced to resign.

Japan's Nuclear and Industrial Safety Agency ordered the shutdown of Tepco's Fukushima plant for up to 1 year [23], and by early 2003 Tepco had suspended operations at all of its 17 nuclear reactors [24]. Several of the other nine nuclear utilities in Japan also reported similar wrongdoings. In September 2002, two of Japan's producers of nuclear power, Chubu Electric Power Co. and Tohoku Electric Power Co., reported "questionable handling of nuclear reactor inspections" [25], and by the end of 2002 a reported 13 nuclear reactors had been shut down [26]. In reaction to the falsification of inspections and repairs, the Japanese Minister of Economy, Trade and Industry stated, "It is absolutely abominable that this incident caused the people's confidence to be largely lost in nuclear power" [27].

These industrial improprieties have heightened public concern over the reporting practices at Japan's nuclear power plants and the integrity of its nuclear industry. Whether they will result in a major reevaluation of the country's nuclear power future by Japanese policymakers and industry is uncertain.

India

India's installed nuclear power capacity is projected to increase from 2,503 megawatts in 2001 to 6,986 in 2025. Currently, India has 14 nuclear power reactors in operation, which make up 4 percent of the nation's electricity generation capacity. Another 7 nuclear power reactors are in various stages of construction. Two 450-megawatt nuclear power reactors, the Tarapur 3 and 4 units, are expected to become operational by 2009, and the two 960-megawatt Kundankulam 1 and 2 units are expected to come on line in 2010 and 2011. The 3 remaining reactors now under construction are not expected to be completed during the *IEO2003* forecast period. Construction has also been started on a large prototype fast breeder reactor.

Middle East and Africa

Iran

Russia is currently working to complete a nuclear power plant at Bushehr, Iran. Initial construction of two reactors at the site was undertaken by Germany in 1974 but was suspended in 1979 (after 85 percent of the construction had been completed) in the midst of the Iranian revolution. During Iran's war with Iraq in the 1980s, Iraqi warplanes attacked Bushehr repeatedly. In 1995, Iran signed an agreement with Russia to complete the two 1,000-megawatt plants at Bushehr. Although both the United States and Israel have expressed strong opposition to Iran's nuclear power program, in July 2002 the Russian Ministry of Atomic Energy (Minatom) proposed the construction of six additional 1,000-megawatt units for Iran [28].

South Africa

South Africa, with two 900-megawatt units located at Koeberg, is the only country in Africa with nuclear power. No new additions to South Africa's nuclear capacity are expected in the *IEO2003* reference case.

South Africa's state utility, Eskom, along with South Africa's Industrial Development Corporation, has been planning to build a pebble bed modular reactor (PBMR). To date, Eskom and the Industrial Development Corporation have a joint shareholding of more than 50 percent in the PBMR project. Eskom's partners in the project originally included BNFL and U.S.-based Exelon; however, Exelon pulled out of the project in April 2002 [29], stating that:

> *Becoming a reactor supplier is no longer consistent with Exelon's strategy. Exelon continues to believe that the PBMR technology has the potential to be viable and successful. Exelon's economic and professional support has done a great deal to advance this technology's development to the point where there is a defined path to the completion of the commercialization of the technology. The project is now positioned for other companies with the appropriate expertise and core business experience to deliver the PBMR plants to power generators such as Exelon Generation.*

The move followed discussions at the end of 2001 between the PBMR Company—set up by the international consortium behind the project to build and market the reactors—and Exelon concerning the estimated cost of a PBMR unit.

At present there is a great deal of uncertainty as to whether the PBMR project will ever reach fruition. In November 2001, the PBMR consortium announced that construction of the first pilot plant would be delayed by up to 12 months [30]. In addition, earlier expectations that PBMRs would achieve revolutionary economic improvements over most existing nuclear technologies have been dampened. David Nicholls, the PBMR consortium's chief executive officer, has stated that the cost of a PBMR will not reach $1,000 per kilowatt of capacity until 32 modules have been constructed [31]. He remains optimistic, however, that the PBMR project will be completed, stating in June 2002 that he had hoped to receive approval from South Africa's government for a test reactor and to complete a pilot unit by 2007 [32].

Western Europe

Nuclear power capacity in Western Europe is projected to decline from 126 gigawatts in 2001 to 96 gigawatts in

2025 in the reference case. The projected loss would amount to 23 percent of the region's total nuclear capacity. Several Western European nations remain committed to their plans to phase out nuclear power; however, those commitments could be modified in view of their emission reduction commitment obligations under the Kyoto Protocol. Finland is the only Western European nation that is committed to the construction of additional nuclear power plants.

Belgium

It appears that Belgium has joined Germany and Sweden in adopting a commitment to phase out nuclear power. In March 2002, Belgium's inner cabinet voted to approve legislation aimed at phasing out the nation's nuclear power plants between 2015 and 2025. Individual plants would be phased out after 40 years of service [***33***]. At the same time, the Belgium Council of Ministers decided to phase out the commercial production of nuclear power in Belgium. In December 2002, Belgium's House of Representatives passed legislation to close the nation's 7 reactors after 40 years of operation, with the first one going out of service in 2015 and the last in 2025. In January 2003, the Belgian Senate voted to phase out all of the nation's nuclear power units not longer than 40 years after their entry into service [***34***]. Belgium's efforts to close its nuclear units could prove difficult, however, in that nuclear power currently provides more than 50 percent of its electricity production. No other nation as dependent on nuclear power as Belgium is has committed to a complete phaseout of its nuclear plants.

United Kingdom

Nuclear power provided 25 percent of the United Kingdom's electricity supply in 2001, but that share is projected to fall to 10 percent by 2025 in the *IEO2003* reference case. Like Japan, the United Kingdom may be approaching a watershed in its nuclear power program (see discussion earlier in this chapter). In February 2002, the government's Performance and Innovation Unit[22] issued a review of UK energy [***35***] which suggested that the government had adopted a more nuanced view of the future role for nuclear power:

> *Nuclear power: a role that cannot yet be defined, since concerns about radioactive waste and low probability but high consequence hazards may limit or preclude its use. Costs of production could fall substantially if new modular designs are effective. Unlikely to compete with fossil fuels in power generation on cost alone, but might have a significant role if low carbon emissions are required. If renewable costs do not fall as anticipated, and/or concerns surrounding waste and risks can be resolved, nuclear would be an obvious candidate for delivering low carbon electricity . . . .*

The report went on to state that any decision to construct new nuclear capacity would be largely an economic one, relying on private investors and new technology that would make the reactors competitive with other generating sources. In January 2003, however, the allegedly pro-nuclear energy minister, Brian Wilson, called for a 5-year moratorium on the construction of new nuclear power plants. An official white paper on energy policy from the prime minister's office was released in early 2003, representing the prime minister's official policy. The document included the following statement: "This white paper does not contain specific proposals for building new nuclear power stations. However, we do not rule out the possibility that at some point in the future new nuclear power builds might be necessary if we are to meet our carbon targets. Before any decision to proceed with the building of new power stations, there will need to be the fullest public consultation and the publication of a further white paper setting out our proposals" [***36***].

Relying more heavily on nuclear power is one means by which the United Kingdom could better meet its Kyoto Protocol commitments. In addition, concerns about energy security may favor the nuclear option. Domestic natural gas production began a downward trend in 2001, and concerns have been raised about the future availability of natural gas supplies, which are expected to come increasingly from foreign sources. On the other hand, possible difficulties in financing future nuclear power projects may have forced the energy minister's hand. The United Kingdom has two domestic nuclear power companies, the government-owned BNFL and the recently privatized British Energy (BE),[23] both of which have had financial difficulties.

Over the past year, BE has encountered several operational and financial difficulties. An unplanned shutdown of BE's Torness 1 nuclear unit in Scotland and operational difficulties at its Torness 2 and Dungeness B units precipitated a decline in BE's share price value [***37***]. In 2001, BE faced insolvency and reported losses of

[22] The Performance and Innovation Unit (PIU) was created in 1998 to review the effectiveness of the central government. The purpose of the PIU is to "improve the capacity of government to address strategic, cross-cutting issues and promote innovation in the development of policy and in the delivery of the Government's objectives." The unit reports directly to the Prime Minister.

[23] When the British government set about privatizing its nuclear power assets, it decided that only the country's most advanced nuclear power reactors could be sold to the public successfully. These included five advanced gas-cooled reactors (AGRs) in England, two AGRS in Scotland, and one pressurized-water reactor in England. Older gas-cooled reactors (GCRs), using MAGNOX technology, were to be retained by the UK government as a public corporation and operated by BNFL, the state-owned nuclear fuel cycle and waste disposal company. In 1996, the more modern reactors were auctioned off in the creation of BE. BE is the largest privately owned nuclear power company in the world.

$778 million for the year [38]. As a consequence, the UK government provided BE with a loan of $640 million to avoid bankruptcy. Concerns over BE's financial health caused three major credit-rating agencies to lower the company's debt rating to below investment grade [39]. BE has said that it is "in preliminary steps of exploring the possibility of selling its interest in Amergen—a 50-50 joint venture with Exelon of the U.S." [40].

BNFL has also encountered operational difficulties. Like BE, BNFL has made overseas investments in nuclear power, including a financial stake in Eskom's PBMR project in South Africa. It is possible that, if future UK government policy turns decidedly pro-nuclear, financial support for nuclear plant construction (with loan guarantees being one of several possible measures) might be forthcoming.

Another factor that may have motivated the moratorium on nuclear plant construction is a sharply reduction in electricity prices under the New Electricity Trading Arrangement (NETA), a power pool reorganization that was adopted by the United Kingdom in 2001. Between March 2001, when NETA was adopted, and March 2002, baseload electricity prices declined by 20 percent and peak prices by 27 percent [41]. Lower electricity prices were blamed for the early closure of the nation's two oldest nuclear plants, Calderhall and Chapelcross [42]. Further, in October 2002, low prices forced PowerGen, the United Kingdom's second largest electricity producer, to announce that it would idle 1,800 megawatts of capacity—26 percent of the company's total generating capacity and 2.5 percent of UK capacity [43].

Finland

Finland is the only advanced industrialized nation, outside of Japan, projected to build new nuclear power reactors. After considering an application made in November 2000 by Finnish utility TVO, the government in January 2002 approved by a 10-6 cabinet vote the building of a new nuclear unit. Finland is governed by a five-party coalition that includes the Green Party, which opposes nuclear power. In May 2002, the Finnish Parliament authorized the construction of a fifth new reactor by a vote of 107 to 92. The reactor is to be in operation in 2009. This is the first authorized construction of a nuclear power plant facility in Europe since the 1986 Chernobyl accident.

In 1993, Parliament rejected a similar proposal, but Finland appears to have adopted a more favorable view toward nuclear energy since then [44]. In a May 2002 Gallup poll, 54 percent of Finns canvassed approved the construction of a fifth unit [45]. In September 2002, TVO announced its specifications for bids to build a new nuclear reactor. Two sites are being evaluated, TVO's existing Loviisa and Olkiluoto nuclear power plant sites [46].

Eastern Europe and the Former Soviet Union

Nuclear power capacity in Eastern Europe and the former Soviet Union (EE/FSU) is projected to decline from 46,321 megawatts in 2001 to 34,722 megawatts in 2025 in the reference case. In Eastern Europe, nuclear power capacity is expected to grow slightly after 2015, with new plants expected to offset the closure of several reactors, many of which are scheduled to be shut down early in response to safety concerns. Since the breakup of the Soviet Union in the early 1990s, the European Union (EU) and the EE/FSU nations have engaged in protracted negotiations to determine the conditions under which several reactors, deemed dangerous by the EU, would be decommissioned early. Table 21 provides a listing of plants for which early closures are being negotiated.

Thus far, both Armenia and Lithuania have been able to negotiate the shutdown of their nuclear power industries with the EU. Lithuania, which relies on nuclear for 78 percent of its electricity supply agreed to shut down Ignalina unit 1 in 2005 and unit 2 by 2009. The Lithuanian parliament agreed to the shutdown of both of the country's nuclear units, with the proviso that there be "sufficient foreign aid" to support closure and that closure should not present "an unbearable burden for the national economy" [47]. A large portion of Lithuania's electricity production is exported and hence a major source of foreign exchange earnings, and the government has asserted that it might build new plants in the future [48]. Lithuania was promised 200 million euros

Table 21. European Union Schedule for Nuclear Reactor Shutdowns in Eastern Europe

Country	Plant Name	Reactor Type[a]	Expected Shutdown
Lithuania. . .	Ignalina 1	RBMK 1500	2005
Lithuania. . .	Ignalina 2	RBMK 1500	2009
Slovakia . . .	Bohunice 1	VVER 440/230	2006
Slovakia . . .	Bohunice 2	VVER 440/230	2008
Bulgaria . . .	Kozloduy 1	VVER 440/230	2003[b]
Bulgaria . . .	Kozloduy 2	VVER 440/230	2003[b]
Bulgaria . . .	Kozloduy 3	VVER 440/230	2006
Bulgaria . . .	Kozloduy 4	VVER 440/230	2006

[a]VVER, water-cooled water-moderated energy reactor (Russian version of pressurized-water reactor); RBMK, Soviet-designed pressurized-water reactor using ordinary water as coolant and graphite as moderator, intended and used for both plutonium and power production.

[b]Kozloduy 1 and 2 were officially closed on December 31, 2002.

Sources: European Commission, "Forecasted Shutdown Dates for Certain Nuclear Power Plants in the EU Candidate Countries," web site http://europa.eu.int/comm/energy/nuclear/decomm7.htm (March 19, 2002); and "Bulgaria Shuts Kozloduy 1 & 2 As Promised, But Not Happily," *Nucleonics Week*, Vol. 44, No. 2 (January 9, 2003), p. 10.

(about $180 million) in grants from the European Commission and 12 other nations to help ease the financial burden of shutting down its Ignalina I power plant.

Armenia, which operates one nuclear power reactor, Metsamor II, agreed with the EU in 1999 to close the plant in 2004, on the condition that the EU provide Armenia with funds to operate the plant safely during the interim. In 2001, both sides agreed to postpone the shutdown until 2006-2007. The Soviet Union had built two nuclear power reactors in Armenia, Metsamor I (now retired) and Metsamor II, both with 376 megawatts of capacity. Metsamor I and II were shut down in 1989 after sustaining earthquake damage. Metsamor II came back on line in 1995. The international community has since pressed Armenia to close Metsamor II. The EU has promised support of 100 million euros and the European Bank for Reconstruction and Development (EBRD) has promised 138 million euros for Armenia to find substitute sources of electric power when Metsamor II is closed [**49**].

Bulgaria and Slovakia have also been involved in negotiations with the EU over the shutdown of their nuclear power reactors. The EBRD has targeted the Kozloduy plant in Bulgaria and the Bohunice plant in the Slovak Republic for early shutdown. In 1999, the EU and Slovakia negotiated an agreement whereby Slovakia is committed to closing down the Bohunice plant between 2006 and 2008. Thus far, negotiations with Bulgaria have been inconclusive.

Recent negotiations between the EU and Bulgaria highlight the difficulty that Eastern European nations and the EU have had in closing nuclear power plants. Nuclear power accounts for nearly one-half of Bulgaria's electricity supply. Bulgaria's nuclear power industry consists of four 408-megawatt nuclear power reactors, Kozloduy 1 through 4, and two 953-megawatt units, Kozloduy 5 and 6. Kozloduy units 1 through 4 are Russian-built VVER 440/230 reactors that were completed in 1974, 1975, 1981, and 1982. The International Atomic Energy Agency (IAEA) declared in 1991 that Kozloduy 1 and 2 were the most dangerous nuclear power units in Europe, but that assessment has been strongly denied by the Bulgarian government [**50**].

In 1999, in an effort to gain entry into the EU, the former Bulgarian prime minister Ivan Kostov and the EU pledged to close units Kozloduy 1 and 2 before 2003 and to agree on a final date for closure of units 3 and 4 by the end of 2002. The EU has taken the position that units 3 and 4 must be closed no later than 2006 [**51**]. At the same time, Bulgaria announced that it intended eventually to restart construction at Belene, where work was stopped in 1990 [**52**]. The EU committed 200 million euros to help Bulgaria close Kozloduy units 1 and 2, and in February 2001 Westinghouse announced that it will modernize Kozloduy units 5 and 6. Bulgaria began the shutdown of Kozloduy units 1 and 2 on December 31, 2002 [**53**].

In 2002, after a series of upgrades on Kozloduy 3 and 4, the IAEA declared that "the safety of units 3 and 4 corresponds widely to the safety levels of plants of the same vintage worldwide" and that "the life of the units could be lengthened by an additional 35-40 years" [**54**]. For several years, Bulgaria has tried to renegotiate the shutdown of Kozloduy 3 and 4. Calling for a peer review by EU member states, the Bulgarian foreign policy minister stated that "should this review reveal that reactors 3 and 4 have not reached the necessary level of nuclear safety for reactors of the same vintage in the member states . . . we shall close them unconditionally. However, if the review shows that the reactors are in a new design condition and can function fully safely for years ahead, if they meet the requirements of the national regulator, the member states shall modify their position paper on the energy chapter, and delete the two units from the list of reactors subject to early closure" [**55**]. In October 2002, Minister of Energy Milo Kovachev stated that the government did not intend to close units 3 and 4.

Russia

Nuclear power capacity in Russia is projected to fall from 20,793 megawatts in 2001 to 14,463 megawatts in 2025 in the *IEO2003* reference case. In 1997, the Russian government approved a nuclear power construction program that would expand capacity to 29,200 megawatts by 2010. It is Russia's announced intention to replace retired nuclear capacity by new construction at the same site, to optimize the use of established infrastructure and personnel. Three advanced reactor designs are envisaged in the program. All this is seen as a precursor to large-scale nuclear energy development after 2010. Russia also plans to refurbish and extend the lives of existing reactors [**56**].

Ukraine

Ukraine has also undergone protracted negotiations with the EU over the fate of the nation's nuclear power industry. Much of the finance for completing two stalled but largely built reactors has recently been pledged. The two units will replace lost output from Chernobyl. Although the units—Khmelnitsky 2 and Rovno 4 (K2 and R4)—today are 80 percent complete, it is not clear that either unit will ever be connected to the grid. Construction on both units was aborted in 1991 after the breakup of the Soviet Union. In 1995, the EBRD and the Group of Seven (G7) signed a memorandum of understanding with Ukraine's government. An important goal of the EBRD and G7 was to encourage Ukraine to shut down its remaining Chernobyl vintage reactors. As a form of compensation, the EBRD agreed to fund the completion of K2 and R4. An understanding was reached that K2 and R4 would be operated at "western safety levels."

The $1.48 billion in funding for the completion and safety upgrade of K2 and R4 was to have come from a number of sources: $580 million from Euratom, $348 million from export credit agencies, $215 million from the EBRD, $123 million from Russia, $159 million from Energoatom (the Ukraine nuclear power utility), and $50 million from the Ukrainian government. As coordinator of the loan package, EBRD's funding became critical to the future of the project. Energoatom and the EBRD had a difficult time negotiating a loan agreement. Initially, the EBRD approved a $215 million loan in December 2000, pending certain conditions involving safety and funding availability. In December 2001, however, loan negotiations foundered over an inability to agree on a future rate structure for sales of electricity from the two plants. Since the beginning of 2002, the negotiations have shown little progress.

Throughout 2002, Ukraine also negotiated with Russia to provide funding for the completion of the K2 and R4 units. Inasmuch as Russian equipment is expected to be used, Russia has an incentive to see the projects through to completion. In mid-2002 Russia agreed to provide 50 percent of the funding for R4 [***57***], and in October 2002 Ukrainian government officials stated that the EBRD had indicated that it was ready to resume talks on project financing [***58***]. In November 2002, Ukraine's Parliament ratified a state loan agreement with Russia, and in December it was signed by the Ukrainian president, Leonid Kuchma [***59***, ***60***].

North America

Canada

Canada's nuclear power capacity is projected to grow from 10,018 megawatts in 2001 to 11,576 megawatts in 2025 in the *IEO2003* reference case. Seven of Canada's nuclear power units were shut down in 1998, and the prospects for bringing them back into service are mixed. In 1997, Ontario Hydro commissioned an analysis of the operating performance of its nuclear reactors, the results of which led Ontario Hydro to retire or suspend the operation of seven units at its Bruce and Pickering nuclear power plants. As a result of the closures—the largest nuclear shutdown in history—Canada lost more than 5,000 megawatts, or one-third, of its total nuclear electricity capacity [***61***].

In July 2000, Ontario Power Generation leased the Bruce A and B power plants until at least 2018 to Bruce Power Partnership, which is owned by British Energy (95 percent) and the power plant employees (5 percent). Bruce Power Partnership also acquired an option to extend the lease to 2043. As of late 2002, Bruce Power was expected to restart Bruce 4 in April 2003 and Bruce 3 in June 2003 [***62***]. Also, in October 2002, Ontario Power Generation announced its intention to bring Pickering 4 back on line by July 2003 [***63***]. Ontario Hydro had initially intended to bring Pickering A's first four units back on line by 2001, but the costs of restarting them mushroomed from $800 million to more than $2 billion [***64***].

United States

Installed nuclear generating capacity in the United States is projected to increase from 98.2 gigawatts in 2001 to 99.6 gigawatts in 2025 in the reference case. The increase is expected to result not from new construction but from uprates of existing capacity. In general, the *IEO2003* forecast views the construction of nuclear power plants in the United States as unlikely, because they are less economical to construct than plants fired by natural gas or coal. In 2001, the U.S. Nuclear Regulatory Commission (NRC) authorized uprates at 22 nuclear power plants, which would increase nuclear capacity in the United States by 1,111 megawatts—the equivalent of adding an additional large nuclear power unit [***65***]. U.S. nuclear facilities also reported a record high average capacity utilization rate of 89.3 percent in 2001, as compared with 66 percent in 1990.

The Bush Administration's energy plan calls for the expansion of nuclear energy "as a major component of our national energy policy" [***66***]. Current U.S. energy goals include an intended new build by the end of the current decade. The Administration's National Energy Policy, released in May 2001 [***67***], supports an expanded role for nuclear power, including the following recommendations:

- Encourage the NRC to expedite applications for licensing new advanced-technology reactors
- Encourage the NRC to facilitate efforts by utilities to expand nuclear energy generation by uprating existing plants
- Encourage the NRC to relicense existing nuclear plants
- Direct the Secretary of Energy and the Administrator of the Environmental Protection Agency to assess the potential of nuclear energy to improve air quality
- Provide a deep geologic repository for nuclear waste
- Support legislation to extend the Price-Anderson Act, which places financial limits on the liability of a nuclear power operator in the event of an accident.

Also in 2001, in a separate measure, the U.S. Department of Energy (DOE) solicited proposals from the civilian nuclear electricity industry to conduct scoping studies "of potential sites for the deployment of new nuclear power plants" [***68***].

Several developments in 2002 showed additional promise for the U.S. nuclear industry:

- In May 2002, the Board of Directors of the Tennessee Valley Authority (TVA) voted to restart Browns

Ferry 1, which has been shut down for 17 years. TVA plans to bring the unit back on line in May 2007, at an estimated cost of $1.7 to $1.8 billion. In October 2002, TVA reached an agreement with Bechtel Power to provide engineering and technical services for the restart. Bechtel stated that it intended to complete the restart by the 2007 deadline [***69***].

- In June 2002, DOE announced the selection of three U.S. electric utilities "to participate in a joint government/industry projects to evaluate and obtain NRC approval for sites where new nuclear power plants could be built" [***70***]. Dominion Resources, Entergy Nuclear, and Exelon have announced plans for early site permit applications. Entergy is focusing on four nuclear plants sites in the South, with particular emphasis on River Bend and Grand Gulf as potential locations for additional reactors.

- In July 2002, President Bush signed legislation designating Yucca Mountain as a site for the disposal of nuclear waste.

- The President's budget proposal for 2003 included a provision to increase spending on nuclear technology research to $46.5 million, from $12 million in 2002.

- The Omnibus Appropriations Resolution signed by President Bush on February 20, 2003, included a provision to extend the Price-Anderson Act. Final approval is dependent on congressional approval of a comprehensive energy bill or a vote on Price-Anderson as a separate piece of legislation.

Not all recent events have been promising for nuclear power in the United States, however. In February 2002, the Davis-Besse reactor in Ohio was shut down after significant corrosion damage to the reactor vessel head was discovered. A hole was found in the reactor's pressure vessel, the result of boric acid seeping through cracks in two of the control rod drive mechanism nozzles. The discovery prompted the NRC to order the inspection of vessel heads in all U.S. pressurized-water reactors [***71***].

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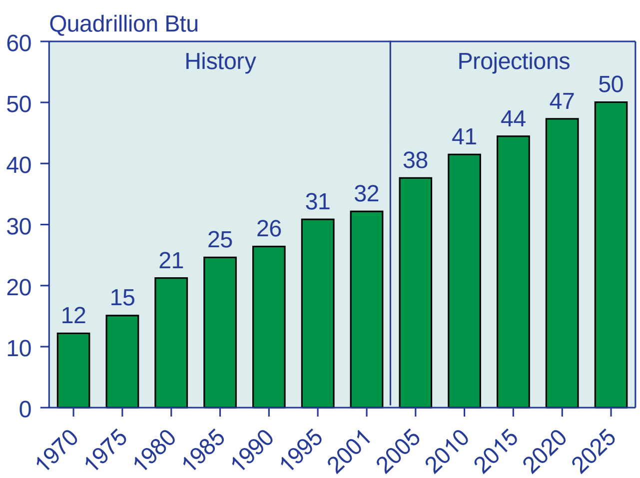
Hydroelectricity and Other Renewable Resources

The renewable energy share of total world energy consumption is expected to remain unchanged at 8 percent through 2025, despite a projected 56-percent increase in consumption of hydroelectricity and other renewable resources.

In the *International Energy Outlook 2003* (*IEO2003*) reference case, moderate growth in the world's consumption of hydroelectricity and other renewable energy resources is projected over the next 24 years. Renewable energy sources are not expected to compete economically with fossil fuels in the mid-term forecast. In the absence of significant government policies 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. *IEO2003* projects that consumption of renewable energy worldwide will grow by 56 percent, from 32 quadrillion Btu in 2001 to 50 quadrillion Btu in 2025 (Figure 69).

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, 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, Malaysia, and Vietnam, among others, are constructing or planning new, large-scale hydroelectric facilities. In September 2002, Malaysia awarded the main construction contract for the 2,400-megawatt Bakun hydroelectric project to Sime Engineering. At the end of 2002, India was poised to begin the final phase of reservoir filling for the 2,000-megawatt Tehri dam [***1***]. The first electricity generating units of China's 18,200-megawatt Three Gorges Dam hydropower project are scheduled to be installed in 2003 [***2***]. Of the 37 electric power projects planned for construction by the Vietnamese government by 2020, 22 are hydroelectric facilities, several with capacities of 600 megawatts or more [***3***].

Figure 69. World Consumption of Hydroelectricity and Other Renewable Energy Sources, 1970-2025



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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 has plans to offer tenders for 34 new hydroelectric energy stations in 2003, with a combined 9,100 megawatts of capacity [***4***], 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 away 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 2,100 megawatts of additional hydroelectric capacity within the next decade [***5***]. In the countries of Eastern Europe and the former Soviet Union (EE/FSU), 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.

Among the other (nonhydroelectric) renewable energy sources, wind power has been the fastest growing in recent years. In Western Europe, Germany, Denmark, Spain, and other nations have installed significant amount of new wind power capacity. Germany installed 2,659 megawatts of new wind capacity in 2001, a national and world record for wind installation in a single year [***6***]. In Spain and Denmark, wind power is doing so well that the governments are considering the elimination of subsidies aimed at promoting its installation.

Wind power also advanced strongly in the United States in 2001, largely because of the threatened end of the production tax credit for wind energy (which has subsequently been extended to December 31, 2003). Sixteen States installed 1,695 megawatts of new wind capacity in 2001, setting a national record and accounting for one-third of the total new wind capacity worldwide. Both houses of the U.S. Congress have included proposals to extend the production tax credit in their versions of the Bush Administration's proposed Energy Bill, which if enacted would extend the program through December 31, 2006 [***7***].

The *IEO2003* projections for hydroelectricity and other renewable energy resources include only on-grid renewables. Noncommercial fuels from plant and animal sources are an important source of energy, particularly in the developing world. The International Energy Agency has estimated that some 2.4 billion people in developing countries depend on traditional biomass for heating and cooking [***8***]. However, comprehensive data on the use of noncommercial fuels are not available and, as a result, cannot be included 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, because there are also few comprehensive sources of international data on their use.

Regional Activities

North America

As of January 1, 2001, the three countries of North America—the United States, Canada, and Mexico—had a combined 176 gigawatts of installed hydropower and other renewable capacity for electricity generation. Hydropower accounts for most of the renewable capacity in the region, with nonhydroelectric, on-grid renewable energy contributing just 17 gigawatts of the total. In the future, capacity fueled by alternative renewable energy sources—particularly wind but also geothermal and solar—is expected to expand more rapidly than hydroelectric capacity; however, hydroelectricity is projected to remain the dominant component of the renewable mix. Renewable energy consumption in the region is projected to increase from 9.4 quadrillion Btu in 2001 to 13.9 quadrillion Btu in 2025.

United States

Potential sites for hydroelectric dams have already been largely established in the United States, and regulatory requirements are projected to limit conventional hydroelectric generation in the future. EIA's *Annual Energy Outlook 2003* (*AEO2003*) projects that U.S. conventional hydroelectric generation will rise from 214 billion kilowatthours in 2001 to 302 billion kilowatthours in 2005 and remain at about that level through 2025.

Nonhydroelectric renewables are expected to account for 4.0 percent of all projected additions to U.S. generating capacity between 2000 and 2025. Generation from geothermal, biomass, landfill gas, solar, and wind energy is projected to increase from 81 billion kilowatthours in 2000 to 189 billion kilowatthours in 2025. Biomass (which includes cogeneration and co-firing in coal-fired power plants) is expected to grow from 38 billion kilowatthours in 2000 to 78 billion kilowatthours in 2025. Most of the increase is attributed to cogenerators, with a smaller amount from co-firing. Few new dedicated biomass plants are expected to be constructed over the forecast period.

The reference case projects substantial increments in U.S. geothermal and wind power. Geothermal capacity, all located in western States, is projected to increase to 5,600 megawatts, supplying 37 billion kilowatthours of electricity (0.6 percent of total generation) by 2025 [***9***]. Wind capacity in the United States is projected to grow by nearly 300 percent over the forecast period, from 4,290 megawatts in 2001 to 12,000 megawatts by 2025. Wind capacity was installed in 22 States by the end of 2001 (Figure 70), and State mandates for increasing the development of renewable energy sources are expected to provide the impetus for the large increment in wind power over the forecast. Where enacted, State renewable portfolio standards, which specify a minimum share of generation or sales from renewable sources, are considered in the U.S. forecast. Federal subsidies for renewables (in particular, wind) are also included in the projections.

Canada

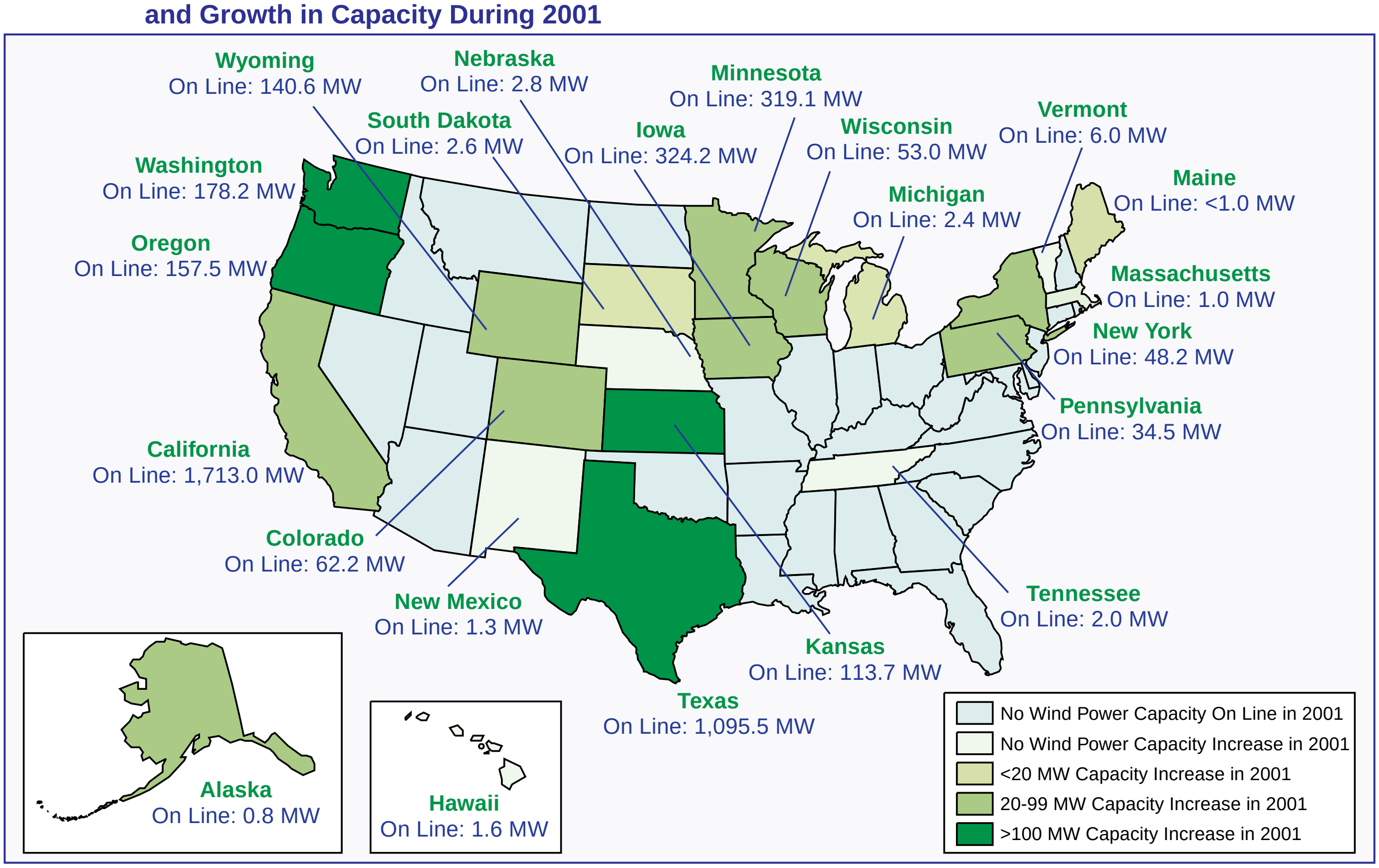
Canada has extensively developed its hydroelectric capabilities. Hydroelectricity is the country's dominant source of electric power, accounting for 67,000 megawatts of the 111,000 megawatts of total installed generating capacity. Canada is one of the only industrialized countries that is expected to expand its mid- to large-scale hydroelectric capacity. Hydro-Québec alone has four sizable hydroelectric projects that are expected to be commissioned within the next decade, including the 480-megawatt Eastmain 1 (scheduled for completion in 2008), the 526-megawatt Toulnustouc (2005); the 882-megawatt Sainte Marguerite 3 (2003); and the replacement of the existing Grand Mère hydroelectric facility with a 220-megawatt facility (2004) [***10***].

Other hydroelectric projects are also under consideration throughout Canada. Canada's Northwest Territories government is considering development of six hydroelectric projects that would add some 11,630 megawatts of new capacity [11]. On the Mackenzie River alone, there are proposals to install 10,500 megawatts of hydroelectric capacity. Other projects include a 200-megawatt run-of-river plant on the Talston River, a 600-megawatt project on the Bear River, and a 270-megawatt project on the Lockhart River. Two small hydroelectric facilities are also under consideration, the 33-megawatt Upper Snare River project and the 27-megawatt Lac La Marte River project. The territorial government has announced its intention to export the electricity from the six projects to Alberta Province as well as to U.S. markets.

Negotiations have continued between Newfoundland and Labrador and Québec provinces on the proposed development of a hydroelectric plant with two dams on the Lower Churchill River in Labrador. In 1998, the two provinces agreed to construct the 3,200-megawatt project, but financing difficulties caused the project to be shelved [12]. In 2001, however, U.S. aluminum company Alcoa, Inc., and the Newfoundland provincial government together funded a feasibility study for the revival of the Lower Churchill project. The new proposal reduced the size of the project to 2,000 megawatts of hydroelectric capacity, with an estimated cost of $1.6 billion [13]. It would still consist of two dams—one at Gull Island and one at Muskrat Falls [14]. Whereas the original project envisioned exporting the electricity produced to the U.S. market, Alcoa would like to use the output to power one or more new aluminum smelters in the province, and the Newfoundland government has also discussed exporting the electricity to neighboring Québec province [15]. The government still must secure consent to construct the Lower Churchill Falls project from the indigenous Innu Nation. If the project receives final approval, it is expected to begin operation by 2012.

In addition to hydropower, Canada has been developing new wind capacity. A reported 198 megawatts of wind capacity was operating in Canada at the end of 2001. Several new wind facilities were commissioned in 2001, including North America's largest commercial wind turbine, a 1.8-megawatt unit at the Pickering Nuclear Generating Station [16]. In February 2002, the first wind project in the province of Saskatchewan began operation, an 11-megawatt project at Gull Lake [17]. The Gull Lake project, located on the Trans-Canada Highway about 200 miles west of Regina, consists of 17 wind turbines. It cost some $15 million to construct and was financed, in part, by an $8 million subsidy from the Canadian government for promoting "green" energy development in Saskatchewan. Provincial utility

Figure 70. Capacity of Grid-Connected Wind Power Plants in the United States as of December 31, 2001, and Growth in Capacity During 2001



Source: International Energy Agency and PWT Communications, *IEA Wind Energy Annual Report* (Boulder, CO, May 2002), p. 218.

Hydro-Québec has also committed to calling for bids to construct wind power capacity and has stated its intention to finance 1,000 megawatts of new capacity between 2003 and 2013 [**18**]. The utility also has plans to support the development of 200 megawatts of forest biomass capacity over the same period.

Mexico

Hydroelectric generation currently provides 20 percent of Mexico's total electricity supply and is its predominant source of renewable energy. Most hydropower sites are in the southern part of the country. A drought in 2002 reduced output from hydroelectric plants substantially, with the Mexican Energy Ministry reporting that hydroelectric reservoir levels were at 10-year lows [**19**].

Although Mexico's hydroelectric capacity is not expected to grow substantially in the *IEO2003* reference case, there are plans to construct new capacity over the next decade. The most ambitious plan is for the construction of the 750-megawatt El Cajón hydroelectric project, the first large-scale hydropower project to be considered for construction in Mexico in more than a decade [**20**]. The state-owned Comisión Federal de Electricidad (CFE) has called for bids to construct what is being called the largest publicly funded infrastructure to be financed by Mexico's Fox Administration. El Cajón is to be located in the municipalities of Yesca and Santa Maria del Oro in Nayarit state on Mexico's west coast. The project is expected to cost an estimated $650 million to complete, with a 610-foot high dam, the highest of its kind in the world. Construction on El Cajón is slated to begin in the first quarter of 2003 and scheduled for completion in the summer of 2007. Construction was expected to begin on January 31, 2003, and to be completed by the end of August 2007.

Of the other, nonhydroelectric renewable sources of energy, geothermal energy is most widely established in Mexico. In 2002, Mexico reported 855 megawatts of installed geothermal capacity, making the country the third largest producer of geothermal electricity in the world, behind the United States and Philippines [**21**]. CFE has estimated that another 1,000 megawatts of geothermal capacity could be developed in Mexico. Currently, however, there are only two geothermal electricity plants under construction, the 100-megawatt Los Azufres plant in Michocán state and the 10-megawatt Las Tres Vígenes plant in Baja California [**22**].

Wind power has had a difficult time advancing in Mexico, although there are rich wind resources in the southern La Ventosa region. By some estimates, La Ventosa could support up to 2,000 megawatts of installed wind capacity [**23**]. Thus far, however, there are only two significant wind projects operating in Mexico, the 1.5-megawatt La Venta project located in La Ventosa and the 0.6-megawatt Guerrero Negro project in Baja California. There are other small wind turbines operating in remote parts of the country.

Nonhydroelectric renewables received some much-needed support in 2001 from the Mexican government, which announced that it would invest $14 million on renewable energy projects in 2002. The government has announced goals to increase wind capacity to 2,000 megawatts by 2006 and solar energy to 13 megawatts by 2009.

Partly as a result of government incentives, wind power capacity is expected to increase substantially in Mexico over the next several years. The Mexican company Fuerza Eólica del Istmo has obtained government permission to construct a 30-megawatt wind farm in the south central Mexican state of Oaxaca [**24**]. Upon completion, the plant will provide electricity for a cement factory owned by Cementos de la Cruz Azul. Fuerza Eólica del Istmo has proposed four additional projects to Mexico's Energy Regulatory Commission, which would add another 215 megawatts of wind capacity. There also some efforts to add solar energy to Mexico's renewable energy mix, with BP attempting to deliver solar generated electricity to some 300 rural communities in 15 municipalities.

Western Europe

With most of its hydroelectric resources already extensively developed, wind remains the fastest growing renewable energy source in Western Europe. According to the European Wind Energy Association, wind energy capacity reached 20,447 megawatts in the fourth quarter of 2002, so that Western Europe now accounts for 74 percent of the world's total wind capacity [**25**]. Germany, Denmark, and Spain continued to see the fastest regional growth in new wind power installations, but several other countries—notably, the United Kingdom and Ireland—also have made advances in wind power development.

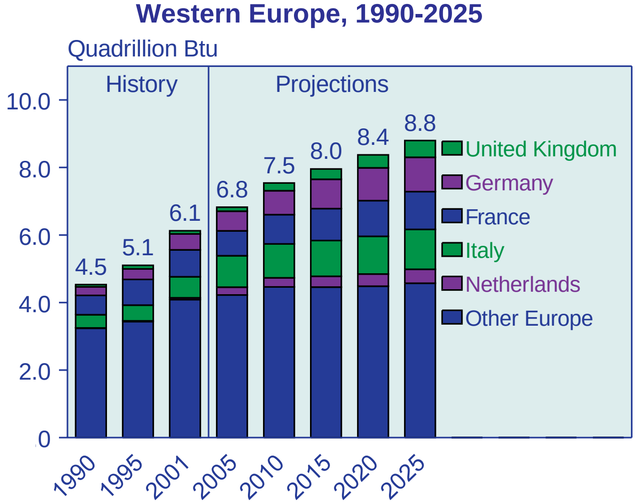
The German market for wind generation remains especially strong. In August 2002, Germany passed the 10,000-megawatt milestone for installed wind capacity mark and estimated that it would reach 11,750 megawatts by the end of the year [**26**]. There are more than 12,000 wind turbines currently operating in Germany, and the government has set a goal of 20,000 megawatts by 2010 [**27**]. In the *IEO2003* reference case, Western Europe's consumption of hydroelectricity and other renewable energy is projected to grow by 1.5 percent per year on average, from 6.1 quadrillion Btu in 2001 to 8.8 quadrillion Btu in 2025 (Figure 71).

One indicator of the success of wind power development in Western Europe is the fact that, after many years of subsidizing wind generation, several countries are now considering eliminating or scaling back the subsidies. Denmark is among the world's most successful wind markets, with approximately 2,500 megawatts of installed wind capacity in 2001, sufficient to meet 12.6 percent of the country's total electricity needs [28]. Wind installations in Denmark have already exceeded the goals set by the government's Energy 21 program in 1996, which called for the installation of 1,500 megawatts by 2005. The program has a target of 5,500 megawatts of wind capacity by 2030, of which 4,000 megawatts will be offshore. In part because of the success of the country's wind program, the Danish government has announced that it will not renew the subsidies for new wind turbines, beginning in 2004 [29].

Spain is also considering removal of its renewable energy subsidies. With 3,337 megawatts of installed wind capacity at the end of 2001, Spain has the second largest amount of installed wind capacity in Western Europe, after Germany [30]. In October 2002, Spanish Energy Minister Jose Folgado stated that renewable energy use in Spain was on schedule to provide up to 25 percent of the country's electricity generation within 10 years [31]. He further noted that wind, biomass, and hydroelectric facilities were strengthened enough so that they could now compete in an open market. The Spanish Minister instead supports the implementation of a "green certificate" program under a Renewable Energy Certificate System. Under the proposed scheme, national authorities would issue certificates verifying the amount of electricity produced, and the certificates could be sold to those who wished to purchase electricity from a certain source, such as wind.

The wind market in the United Kingdom (UK) has developed more slowly than those in other countries. Difficulties in obtaining siting licenses and public aversion to wind farms have made it difficult to install wind turbines [32]. At the end of 2001, 468 megawatts of wind capacity had been installed in the UK, far less than the 2,676 megawatts of wind capacity with power purchase contracts under the Non Fossil Fuel Obligation, which had been used before 2001 to secure funding for renewable energy sources.

Figure 71. Renewable Energy Consumption in 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 (2003).

In April 2002, the UK enacted its newest Renewable Obligation (RO) under the New Electricity Trading Arrangements program [33], which replaced the Non-Fossil Fuel Obligation program used to collect taxes to support the country's nuclear power plants and renewable energy projects. Under the terms of the new RO, electricity suppliers are required to provide 3 percent of their electricity sales from approved renewable energy sources until March 2003, and the requirement rises to 10.4 percent of sales in March 2011. If the supplier cannot meet its requirements, it must purchase renewable certificates. The cost of the certificates has been set at about $47 (30 British pounds) per megawatthour, which may be adjusted after April 1, 2003, in accordance with the retail price index for electricity [34]. The RO also includes provisions for financing energy crops and offshore wind programs and establishes a $158 million renewable energy fund.

Several renewable energy projects advanced in the UK in 2002. In July, the 30-megawatt Bein an Tuirc wind project began operating at Carradale on the Kintyre peninsula in Scotland [35]. The project consists of 46 660-kilowatt turbines, which are expected to provide enough electricity to supply 25,000 homes. It is hoped to be the first of three wind farms developed by Scottish Power. The $32.3 million project is capable of producing power very efficiently, because it is situated on the Kintyre peninsula where wind resources are among the best in Western Europe, according to the UK Department of Trade and Industry. Scottish Power hopes to install at least another 785 megawatts of wind capacity by 2010, which would meet more than one-half of Scotland's renewables target.

In June 2002, Canadian oil producer Talisman Energy announced that it would install a 500-megawatt offshore wind project near one of the UK's oil fields off the northern coast of Scotland [36]. The UK initiated a feasibility study of the proposed project, which will consist of up to 120 turbines, and in July 2002 consent was granted for its construction. When it is completed it will be the largest offshore wind project in the UK. The 90-megawatt North Hoyle wind project, to be constructed about 5 miles from the North Wales Coast in Denbighshire, is scheduled for completion by the end of 2003. It will supply electricity for more than 50,000 homes.

Ireland has only recently begun introducing wind-powered electricity to its energy mix. To encourage the development of renewable energy capacity in the country, the Irish government approved $404 million for renewable energy projects, with the hope that the investment would double the amount of electricity generated from wind, biomass, and hydroelectric resources [***37***]. In July 2002 the Irish energy company Airtricity announced that it had begun construction on Ireland's first wind farm. The 25-megawatt facility is being constructed on the Irish west coast, near Sligo. The project was expected to cost approximately $34 million and to be operational by spring 2003.

Eastern Europe and the Former Soviet Union

There are only a few plans to expand the use of renewable resources in the countries of Eastern Europe and the former Soviet Union (EE/FSU). Much of the increment in hydroelectricity from 2001 to 2025 is expected to be in the form of repairing and expanding existing facilities that suffered from a lack of maintenance during the Soviet era. In general, renewables are not competitive in the FSU, where fossil fuel resources are abundant and demand for clean forms of electricity can be met with cheaper natural-gas-fired capacity. There has begun to be some modest activity, however, toward exploiting wind resources and other nonhydroelectric renewable energy resources among the former Soviet Republics. Renewable energy demand in the FSU is projected to increase by 0.8 percent per year over the forecast period. In Eastern Europe, the growth rates projected for hydroelectricity and other renewables are substantially higher than those for the FSU at 2.2 percent per year, reflecting the relatively small amount of renewable capacity currently installed in the region. By 2025, the reference case projects that use of hydropower and other renewable energy sources in Eastern Europe will be 43 percent of the current level in the FSU (Figure 72).

Former Soviet Union

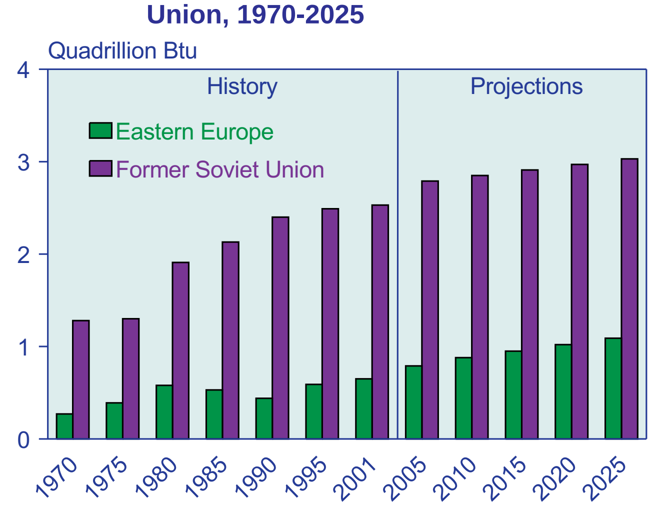
Although most of the development of hydroelectric resources in the FSU today consists of updates and repairs to old infrastructure, Armenia has announced plans to construct several new hydroelectric projects over the next several years. Armenia has developed plans to construct 38 small and 3 large hydroelectric power plants, with a combined installed capacity of 296 megawatts [***38***]. Two of the three large hydropower projects, the 60-megawatt Lori Berd and the 75-megawatt Shnokh, are to be located in the northeastern part of the country. The third, the 79-megawatt Megri, is to be sited on the Araks River on the Armenian-Iranian border. The estimated cost of the Megri project, which would take 5 years to complete, is between $60 million and $80 million. The World Bank and the European Bank for Reconstruction and Development have committed to part of the funding for the $300 million program. No construction schedule has yet been submitted, and the Azerbaijan government is protesting the plan, arguing that its Nakhichevan region would be adversely affected.

In Azerbaijan, the 4,000-megawatt Yenikand hydroelectric project was completed in 2000 [***39***]. Construction on Yenikand began in 1985, but work was suspended in 1987 as a result of financing difficulties. Construction resumed in 1996 with the help of a $53 million loan from the World Bank. In 2001, the restoration of the $41 million Mingechaur hydropower project was completed. The 360-megawatt project is located on the Kura River.

Georgia has announced plans to construct two new hydroelectric projects on the Rioni River, the 250-megawatt Namakhvani and the 100-megawatt Zhoneti. The country is attempting to attract foreign investment to fund the additions. In September 2001, the Georgian-Chinese Energokorporatsia Vostoka company opened the first phase of the 24-megawatt Khador hydroelectric project near the Georgian-Russian border in the eastern Kakheti region. The project is scheduled to be completed before the end of 2003. In January 2002, Georgia announced that China's Sichuan Machinery, which is constructing Khador, would invest $10 million in a second hydroelectric station in Georgia. The 9.3-megawatt plant will be built on the Chelta River in the Kakheti region.

There are also plans to expand hydroelectric capacity in Russia. The largest project currently under construction in Russia is the Bureyskaya hydroelectric project. Construction on this 2,320-megawatt project in the Russian Far East region of Amur was started in 1976, but work was suspended because of difficulties in securing

Figure 72. Renewable Energy Consumption in Eastern Europe and the Former Soviet Union, 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 (2003).

financing for its completion [40]. Unified Energy System of Russia (UES) resumed construction on Bureyskaya in 2000, and it is now scheduled to begin operating by the end of 2003. UES has also announced a scheme for constructing a 20,000-megawatt hydroelectric station, the Turukhan project, on the Nizhnaya Tunguska River [41]. According to UES, Turukhan would be used to supply electricity to western parts of Russia, as well as for exports to Europe. On a smaller scale, in 2002 construction began on the 15-megawatt Gunibskaya power station on the Karakoysu River in the Russian Republic of Dagestan [42].

The FSU is seeing increasing interest from the international community for participation in the development of nonhydroelectric renewable energy resources. Russia's first commercial wind project began operating in the Kaliningrad region in July 2002 [43]. The 45-megawatt Kulikovo project was constructed by UES and the Danish company SEAS, and there are already plans to construct a second wind facility offshore in the same region.

Estonia is another FSU country that has made moves to develop wind-powered electricity generation. In October 2002, the country's first commercial wind project, the Virtsu Wind Park, began operation [44]. The 1.8-megawatt project was constructed as a joint venture between state-owned utility Eesti Energia, ÖU Roheline Ring, and German wind turbine manufacturer Enercon GmbH at an estimated cost of $2.4 million, funded by the German Federal Ministry of Economics and the Estonian Regional Development fund. The utility has also granted a licence to Estwind Energy (which has subsequently been acquired by Canadian Secureview Systems, Inc.) to install a total of 3 megawatts of wind capacity, divided between Saamemaa and Tostamaa [45]. Estonia is particularly interested in renewable energy projects to meet its renewable requirements for European Union membership. The country hopes to increase the renewable share of its total energy use to 10 percent (from 1 percent at present), but no timetable has been set. Eesti Energia established a subsidy for renewable energy generation as an incentive for increasing renewable energy projects.

Eastern Europe

Among the countries of Eastern Europe, Romania has perhaps the greatest potential to expand its use of hydroelectricity. To date, only about 6 megawatts of hydroelectric capacity has been installed in Romania. In September 2001, state-owned Hidroelectrica and the Romanian Ministry of Industry and Resources tendered 21 hydroelectric projects, involving the completion of 36 hydroelectric plants by 2004 at an estimated cost of $1.3 billion [46]. Hidroelectrica is attempting to finalize deals for the first 9 of the 21 projects that have received bids from potential investors, which include Italy's Enel and France's Electricité de France. Enel signed an initial agreement to undertake a feasibility study on eight hydroelectric facilities on five rivers, including the 75-megawatt Comesti-Movileni project on the Siret River, the 116-megawatt Cornetu-Avrig project on the Olt River, and the 22-megawatt Valea Sadului on the Jiu River, as well as a water supply tunnel at the Raul Mare Retezat facility [47]. The company has estimated the cost of work on the entire set of projects at $400 million to $500 million. Hidroelectrica has announced that it will make a decision about development plans for the remaining 12 projects in the first quarter of 2003.

Several other East European countries have made plans to renovate or add hydroelectric capacity. In Hungary, there are plans to modernize the 28-megawatt Kiskorei Vizeromu hydroelectric facility [48]. A consortium led by Hungarian-based Siemens RT estimates that the $10.4 million upgrade will be completed by 2006. U.S. Triangle General Contractors has begun a feasibility study for the upgrade of the Koshnjentin hydroelectric project in Kosovo, near the Albanian border [49]. Local authorities are also investigating the possibility of constructing a new hydroelectric project at Zhur. Macedonia is beginning to add several small hydroelectric facilities. In July 2002, construction on the fifth of six hydroelectric plants in the Stezevo cascade began [50]. The 8.8-megawatt Lera hydroelectric project is scheduled for completion in early 2004. The project is being financed through a $7.5 million credit from the Spanish government. The Stezevo hydroelectric system will be completed with a 2.5-megawatt power plant near Kazani.

Plans to expand Bulgaria's hydroelectric capacity have been hampered somewhat both by financing difficulties and by protracted efforts to privatize the country's electric power sector. Privatization of the electric utility sector is expected to be completed by June 2003, with the sale of seven Bulgarian electricity companies [51]. State-owned Natsionalna Elektricheska Kompania (NEK) has been unbundled into three generating companies, in addition to distributors. Twenty-two hydroelectric power plants are to be sold to private companies.

NEK has announced plans to renovate or complete a number of hydroelectric projects, most notably the $300 million Gorna Arda project. Plans to renovate the 170-megawatt Gorna Arda ran into difficulties in 2000 when Turkey's Ceylan Holding faced financial problems. Italy's Enel expressed an interest in taking on the project in late 2001 and by mid-2002 had been chosen by an international tender to complete the project, but shareholders of the Gorna Arda project were unable to oust Ceylan Holding, which owns 31 percent of the joint venture. The project remains stalled, and deadlines for the completion of Enel's feasibility study for Gorna Arda have been repeatedly delayed [52]. NEK financed the construction of the first plant in the complex, the Madan hydroelectric project, which is scheduled for completion in early 2003. Enel has also launched a feasibility study for a hydroelectric project to be sited in central Bulgaria on the Cherni Osum reservoir [*53*]. If the outcome of the study is positive, construction on the estimated $82 million project could start as early as fall 2003.

One Eastern European country that has made some substantial moves to increase its wind-generated electricity capacity is Poland. Poland is expected to join the European Union in 2004 and, as a result, must increase its renewable energy use to meet EU obligations of 12 percent of total electricity generation by 2010 [*54*]. Poland has stated it will spend $3.2 billion over the next decade for the development of wind, water, and biomass (i.e., straw) generators, as well as solar panels. In April 2002, the German company P&T Technology announced that it would install 1,500 megawatts of wind capacity before 2012. The first 220 megawatts of capacity—wind turbines located near the city of Poznan and in northeastern Poland—are expected to begin operating by June 2003.

Central and South America

The hydroelectric resources of Central and South America have been widely developed. Many countries in the region rely on hydropower for more than 70 percent of their total electricity generation. Such heavy dependence on hydroelectric resources can be problematic when a nation is faced with drought conditions. In the 2000-2001 period, for instance, Brazil experienced severe droughts that threatened blackouts and electricity shortages. The government responded with mandatory conservation rules, which finally were lifted in the early part of 2002, but the government also saw the urgency of diversifying the electricity supply mix. Many South American countries are working to develop natural-gas-fired electricity generation to lessen dependence on hydroelectricity and the impact of future droughts on their economies, but plans are also under way in the region to expand hydroelectric power, as well as other renewable energy sources. The *IEO2003* reference case projects 1.2-percent average annual growth in the region's renewable energy use from 2001 through 2025 (Figure 73).

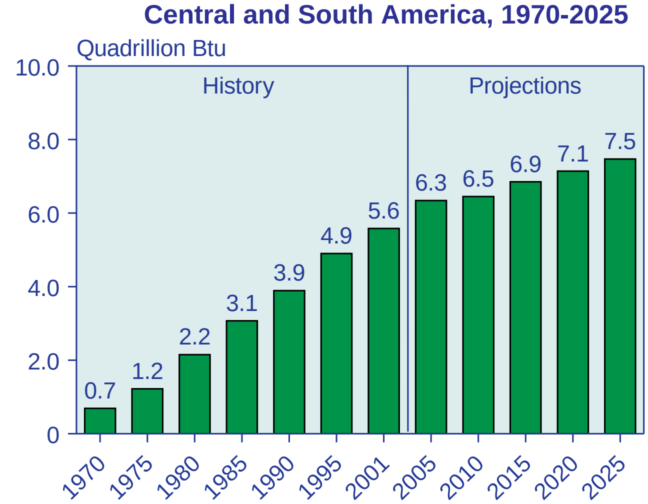
Brazil

Despite the fact that many parts of Brazil experienced severe drought over the past 2 years, there are still plans to add to the country's hydroelectric capacity both in the northwest, where the drought was less extreme than in other parts of the country, and in the southeast, where electricity demand is growing fastest. In July 2002, Brazil's power regulator Agência Nacional de Energia Eléctrica (Aneel) awarded concessions to several foreign and Brazilian consortia to construct and operate an additional eight new hydroelectric power plants in the northeast and central regions. The projects, adding 1,600 megawatts of capacity in five states, are expected to cost approximately $1.2 billion [*55*]. Canadian aluminum producer Alcan, Inc., won two concessions to build three small plants [*56*]. Alcan is also constructing five other small plants in Brazil, which should satisfy the company's 300-megawatt needs. Three of the new plants should begin operating in 2006, another four in 2007, and the last one in 2008.

A consortium led by Belgian energy company Tractebel (and including Brazil's Camargo Correa Energia, Companhia Vale do Rio Doce, BHP Billito, and U.S. Alcoa) was successful in attaining the contract to build, own, and operate the largest of the eight projects, the 1,087-megawatt Estreito hydroelectric project in northern Brazil [*57*]. Estreito is to be constructed on the Tocantins River, on the border between the states of Tocantins and Maranhão. The first unit of the facility is scheduled to begin operating in 2007. The consortium has a number of other hydroelectric projects currently under construction, including the 300-megawatt Aimorés, the 140-megawatt Candonga, and the 180-megawatt Funil, all located in the southern state of Minas Gerais [*58*].

The expansion of Brazil's hydroelectric power is expected to continue in 2003, when Aneel is expected to auction concessions for an additional 34 hydroelectric energy stations [*59*]. The new power plants will add 9,100 megawatts of electricity capacity and require investment of around $4 billion. Aneel has stated that Brazil's installed electric capacity increased by 6,244 megawatts in 2002 and will expand by another 15,709 megawatts in 2003 and 2004 and 4,675 megawatts in 2005, based on new hydroelectric plants that either are

Figure 73. Renewable Energy Consumption in Central and South 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 (2003).

under construction or have been approved. In contrast, 20 new thermal power plants are expected to add 7,000 megawatts to the country's electricity system by 2005.

Brazil is currently the world's largest consumer and producer of ethanol from sugar cane, which is widely used in the country's automotive sector. Alcohol fuel use is a legacy from the Proácool program, which was created by the government in response to the 1973-74 oil embargo to lessen Brazil's dependence on oil imports and allow it to develop its own oil production and reserves [***60***]. About 3 million older cars still in circulation in Brazil run on 100 percent ethanol (hydrous ethanol vehicles), and the all the country's motor fuels contain 25 percent ethanol. Only about 1 percent of all the new cars sold in Brazil today are hydrous ethanol vehicles; however, there is renewed government interest in reviving the Proácool program both for domestic consumption and to serve growing export markets. There is a 10-year ethanol accord between Brazil and Germany, under which Germany will receive carbon credits under the terms of the Kyoto Protocol by paying for the production of 100,000 new hydrous ethanol cars.

The Brazilian government has also made substantial efforts to encourage the development of wind-generated electricity. In October 2002, only eight wind stations were operating in Brazil, with a total capacity of 21.4 megawatts [***61***]; however, more than 5,100 megawatts of new wind capacity has been approved for construction by federal regulator Aneel. In 2001, Aneel approved 38 wind projects with a total of 3,337 megawatts of capacity, and by October 2002 another 29 projects had been approved, with a combined capacity of 1,793 megawatts. The projects are sited in the Brazilian states of Bahia, Ceará, Pernambuco, Piauí, Rio de Janeiro, and Rio Grande do Norte. All the projects are scheduled to become operational between 2002 and 2007; however, their construction will depend on the ability of developers to obtain financing and purchase power agreements.

Over the past 2 years Brazil has taken a number of steps to increase the use of alternative renewable energy sources. In July 2001, in the midst of the electricity crisis brought on by persistent drought, the Power Crisis Management Chamber established an emergency wind energy program, Proeólica, with the goal of adding 1,050 megawatts of wind capacity to the national grid by December 2003. Under Proeólica, the federal government guarantees a "beneficial" purchase of wind-generated electricity by state utility Eletrobras for at least 15 years. Further, Brazil's legislature passed Law 10.438 (or Proinfa) in April 2002, establishing incentives for alternative electricity sources. In addition, the state government of Rio de Janeiro passed a law in January 2002 that authorizes tax benefits for wind, solar, and biomass electricity generation projects [***62***]. The law also encourages regional incentives for generation projects that use nonhydroelectric renewable energy sources.

Other Central and South America

Despite economic and political problems in many countries of Central and South America, some renewable energy projects have advanced in the region. Hydroelectric power still dominates the renewable energy picture in the region. In Peru, new hydroelectric projects were banned under the former Fujimori administration in an effort to attract investment in the country's Camisea natural gas fields. The ban was lifted by the Toledo administration, and a spate of new hydroelectric projects are now under development in Peru. The country has 11 new hydroelectric dams currently planned or under construction, at an estimated total cost of $1.5 billion. All the projects are expected to be operational within the next 6 years, adding some 1,500 megawatts of capacity to the Peruvian electricity grid [***63***]. They include the $304 million, 130-megawatt Yuncan—the only state-owned project among the eleven—which is already one-third complete and is scheduled to begin generating electricity by July 2004. The project has been funded by the Japanese government.

Other Peruvian hydroelectric projects include a 100-megawatt project in the La Libertad region to be constructed by the Taruncani Generating Company; the 27-megawatt Poechos project to be constructed by Sinersa near the Ecuadorian border; and the 270-megawatt El Platanal project to be built in Lima by Cementos Lima. El Platanal is scheduled for completion in July 2006. Work on the 96-megawatt Marañon and 525-megawatt Cheves hydropower projects is to be completed by February 2005 and November 2009, respectively. The Peruvian privatization agency, ProInvestment, is planning to auction the concession to build and operate the 143-megawatt Olmos hydroelectric project on the Huancabamba River in Northern Peru [***64***]. The project is expected to cost $245 million, with the Peruvian government contributing $77 million to the costs over the 3-year construction period.

There is increasing interest among several Central and South American countries in developing their non-hydroelectric renewable energy resources. In September 2002, Colombian utility Empresas Públicas de Medellin (EPM) offered two tenders for the construction of the 20-megawatt Jepirachi wind project in the Guajira province on the Atlantic coast [***65***]. Jepirachi is scheduled for completion by October 2003 [***66***]. The $21.5 million project will be the first developed by Colombia under the provisions of the Kyoto Protocol's Clean Development Mechanism, with the backing of the World Bank's Prototype Carbon Fund. Launched in 2000, the Prototype Carbon Fund is a mutual fund that invests in clean technologies in developing countries and in the EE/FSU.

Resulting reductions in greenhouse gas emissions are to be verified and then transferred to the fund's contributors in the form of emissions reduction certificates that may be used by the contributors to meet their emissions targets under the Kyoto Protocol.

Geothermal energy is also being increasingly exploited in the Central and South America region. Countries in the region added some 242 megawatts of geothermal generating capacity between 1990 and 2000, more than doubling the use of geothermal energy from its 1990 level of 165 megawatts [***67***]. There are plans to expand Nicaragua's geothermal capacity beyond the current level of 70 megawatts. In 2002 construction began on a $140 million geothermal project near Leon, about 56 miles northwest of Managua [***68***]. The San Jacinto-Tizate steam field will be the country's first fully private geothermal power facility. The first phase of the project consists of a 10-megawatt pilot plant, which will eventually be expanded to 66 megawatts.

El Salvador is also expanding its geothermal capacity, adding 38 megawatts of capacity. Italy's Enel GreenPower has entered into a joint venture with El Salvador's state-owned geothermal generator, Gesal, to develop the project at an estimated cost of $91 million. Gesal currently operates two geothermal plants in El Salvador, the 95-megawatt Ahuachapán and the 66-megawatt Berlín.

Developing Asia

In developing Asia, much of the development of renewable resources is expected to center on increasing the amount of mid- to large-scale hydroelectric capacity. The region has some of the world's largest hydroelectric facilities either planned or under construction. China has particularly ambitious plans to increase hydroelectric capacity, including the 18,200-megawatt Three Gorges Dam project and the 5,400-megawatt Longtan project, both of which are under construction [***69***]. Other countries in the region, including Vietnam, Malaysia, and India, also have plans to expand their use of large-scale hydroelectricity over the next decade in an effort to diversify electricity sources and meet the rapidly growing demand for new electricity to fuel their expanding economies. Consumption of hydroelectricity and other renewables is expected to more than double among the nations of developing Asia, from 5.1 quadrillion Btu in 2001 to 11.0 quadrillion Btu in 2025 (Figure 74).

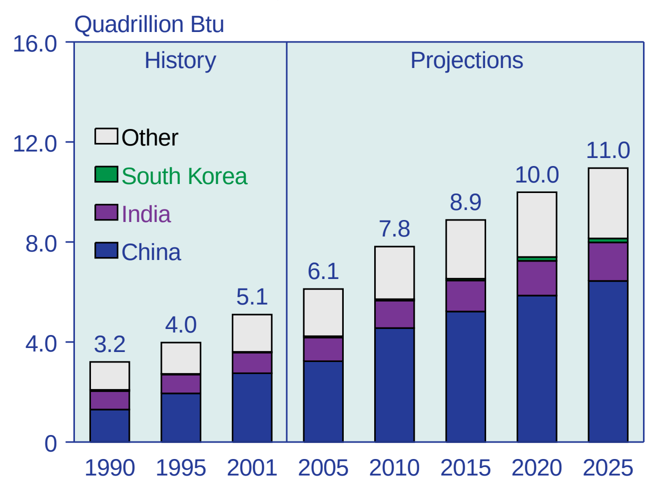
China

Over the next decade, China has extensive plans to expand its hydroelectric capacity above the current 79,000 megawatts of installed capacity. The Three Gorges Dam project remains the largest and most ambitious hydropower project currently under construction. With the displacement of more than a million people living around the construction site and destruction of significant architectural sites, it is also among the most controversial projects in the world today. Despite criticism from the international community, the Chinese government has been adamant in its pursuit of the 18,200-megawatt project, which will cost $25 billion or more to complete [***70***]. The government argues that the dam is needed both to provide electricity to meet rapidly growing demand in the country's urban areas and to control devastating flooding along the Yangtze River.

In November 2002, work on the Three Gorges Dam project reached a significant milestone with the successful blocking of the Yangtze River [***71***]. The river's waters are now being channeled through diversion holes in the partially completed dam. The dam's reservoir is scheduled to begin to be filled in early 2003. By the end of 2003, the project is expected to begin generating electricity with the installation of the first four 700-megawatt generators [***72***]. Three Gorges Dam is expected to become fully operational in 2009.

Several additional hydroelectric projects are now being developed in China. The Yellow River Hydro Electric Corporation is developing 25 hydropower projects on the Yellow River with a combined 15,800 megawatts of installed electricity capacity [***73***]. In addition to Three Gorges, the Chinese government has several other large-scale hydroelectric projects either under construction or in the planning stages. In July 2001, construction began on the 5,400-megawatt Longtan project on the Hongshui River, which is expected to begin operating in 2007. Other large-scale projects under construction

Figure 74. Renewable Energy Consumption in Developing Asia, 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 (2003).

include the 1,350-megawatt Dachaoshan hydroelectric project, scheduled to be completed by the end of 2003, and the 4,200-megawatt Xiaowan project, scheduled to be completed in 2012. Both are located on the Mekong River. Proposals have been submitted for the 14,000-megawatt Xiluodo project (on the upper portion of the Yangtze River, known locally as the Jinsha River); 6,000-megawatt Xiangjiaba project (Jinsha River); 5,000-megawatt Nuozhadu project (Mekong River); and 1,500-megawatt Jinghong project (Mekong River) [74].

In addition to the hydroelectric expansion taking place in China, there has also been some progress in installing alternative, nonhydroelectric renewable energy sources. The government has instituted a number of programs to increase the use of nonhydroelectric renewables. The Brightness Program was launched in 1996 to encourage the use of solar panels and wind turbines for electricity generation with low-cost loans. Pilot projects under the program have been set up in the regions of Inner Mongolia, Gansu, and Tibet. The ultimate goal of the program is to provide electricity from these sources to 8 million people by 2005 and to 23 million people by 2010.

In an effort to boost interest in wind-powered electricity generation, the Chinese government has announced that it will cut the value-added tax on wind-generated electricity by half, reducing the average cost of wind generation by between $6 and $7 per megawatthour. Wind projects have also found funding from international sources that are interested in reducing China's dependence on coal use. The Asia Development Bank is providing loans worth some $58 million to erect wind projects in Xinjiang, Liaong and Heilongjiang provinces. One of the projects is a 200-megawatt wind farm in Xinjiang that will be China's largest wind installation upon completion in 2003 [75]. Another project to be funded with foreign investment is the 100-megawatt Hulai Shipaishan wind project in Guangdong province [76]. Tenders for the $120 million project were offered by local government authorities in Hulai county.

India

At present, India has 25,140 megawatts of installed hydroelectric capacity[77]. With an overall development potential of 84,000 megawatts, there are ample resources still to be exploited [78]. Numerous government-funded hydropower projects are under construction throughout the country, including the 1,500-megawatt Nathpa Jhakri project in Himachal Pradesh state and the 1,000-megawatt Tehri project in Uttar Pradesh. At the end of 2001 India announced that it would revive construction of the $1.2 billion Tehri hydroelectric dam project [79]. The final two tunnels associated with the first phase of the project were scheduled for completion in December 2002, and Tehri should begin supplying electricity in August 2003 [80]. There are additional plans to expand Tehri's capacity to 2,000 megawatts in subsequent phases, but no work beyond the initial phase has been approved.

A number of smaller hydroelectric facilities have also been approved for construction in India. In Himachal Pradesh the government awarded private power developers permission to construct eight hydroelectric projects in 2002 [81]. The projects range in size from the 10.5-megawatt Baragaon project to the 100-megawatt Malana II and Sainji projects. The government of Himachal Pradesh has announced its intention to develop 20,000 megawatts of its hydroelectric potential. As of 2002, 3,900 megawatts of hydroelectric capacity had been installed in the state, with another 6,800 megawatts under construction.

Other Developing Asia

Vietnam has recognized the need to increase its electricity generation in order to power its growth in industrial production and gross domestic product, which have been expanding by 6 to 7 percent annually in recent years. Hydroelectricity is expected to make a large contribution toward meeting the increased demand for electricity. The state-owned Electricité de Vietnam (EVN) has announced plans to add 37 new electric power plants by 2020, to the existing 18 power plants [82]. Twenty-two of the planned power projects are hydroelectric plants, and the rest are to be fueled by oil, natural gas, and coal. EVN has announced its intention to fund approximately one-third of the investment needed to construct the new projects, with the rest to come from private and foreign investment.

In 2002, Vietnam's second largest hydroelectric project (after the Hoa Binh project), the 720-megawatt Yaly Falls became fully operational [83]. The $546 million project, located on the Se San River in the central part of the country, is expected to supply about 10 percent of Vietnam's total electricity generation. The 475-megawatt Ham Thuan / Da Mi hydroelectric project in the southern part of the country is also nearly completed [84]. In 2002, construction began on the 300-megawatt Dai Ninh in the central province of Lam Dong and the 300-megawatt Se San in the central province of Gia Lai. Construction is expected to begin by March 2003 on the 324-megawatt Na Hang hydroelectric project [85]. The $500 million project is scheduled to begin generating electricity in 2006 and to be fully operational by 2007. Finally, in October 2002, the Vietnamese government gave final approval for construction of the 2,400-megawatt Son La hydroelectric project, which will become the country's largest hydroelectric facility [86]. Construction on the $1.7 billion project is expected to begin in 2004 and to be completed in 2012.

In 2002, Laos made some progress in reviving construction on the controversial Nam Theun 2 hydroelectric project. Construction of the 920-megawatt, $1.2 billion project has been delayed since 1997, pending a trade agreement between Laos and Thailand on the output from the project [**87**]. Electricity produced by Nam Theun was originally to be sold exclusively to Thailand, which has offered to sign an initial 13-year power purchasing agreement with Laos after indicating that it cannot support the original 25-year agreement for the electricity from the project. In 2002, a consortium led by Electricité de France was awarded a build-operate-transfer contract for Nam Theun 2. If the Laotian and Thai governments are able to finalize a power purchase agreement, Nam Theun 2 could be in operation by 2008 [**88**].

The Malaysian government in 2002 reiterated its commitment to develop its hydroelectric resources, citing the country's need to diversify the electricity fuel mix away from an overreliance on natural-gas-fired generation. State-owned utility Tenaga Nasional Bhd completed construction of the 600-megawatt Sultan Ismail Petra dam in the northern state of Kelantan in 2002 and is considering a 1,000-megawatt project in Pahang state. The controversial 2,400-megawatt Bakun hydroelectric project also progressed slightly in 2002. The main construction contract for the project was awarded to the Malaysian company, Sime Engineering in September, and in October a consortium was formed to supply materials and services to support construction of the $3.6 billion project [**89**].

The Bakun project has been the subject of much controversy since it was conceived in the 1980s, both because of its cost and because of its potential impact on the environment. The project was scaled back in 1998, during the Asian economic crisis, which made the project too expensive to pursue given the drop in electricity demand associated with the recession. In 2001, however, the government announced that it had reconsidered, and the project was returned to its originally planned capacity [**90**]. Environmentalists argue that the reservoir required to supply water to Bakun will mean that an area the size of Singapore will have to be flooded, displacing as many as 15 villages of the indigenous Iban people in Sarawak state and destroying the habitat of up to 100 endangered species [**91**].

Among the countries of developing Asia there has also been some recent interest in developing renewable energy sources other than hydropower. South Korea and Taiwan, for instance, have expressed increasing interest in developing their wind resources. In 2002 the South Korean government announced that it had approved plans to construct a 99-megawatt wind project on the country's east cost at Daekwanryung in Kangwon province [**92**]. The $110 million project is to be constructed in two phases, the first consisting of 28.5 megawatts of capacity scheduled to be completed by July 2004 and the second phase consisting of 70.5 megawatts of capacity to be completed by November 2005. A second 6-megawatt project is planned for construction by state-owned Korea Southern Power. It will be sited at Yongsuri on the island of Cheju. Construction was scheduled to begin in March 2003 and to be completed by April 2003 at an estimated cost of $12.3 million. Another 150-megawatt, $230 million multi-phase wind project funded by local and national government organizations is also under construction on Cheju, with final completion scheduled for 2006.

The government of Taiwan has established a goal of installing up to 1,500 megawatts of wind capacity by 2020 [**93**]. State-owned Taiwan Power Company announced in 2002 that it would invest $144 million in wind power projects between 2002 and 2007. At the end of 2001, the company completed a $4.3 million, 2.4-megawatt wind power project on Penghu Island. It has also announced plans to install up to 80 megawatts of wind capacity in Taichung county.

Industrialized Asia

The extent to which available renewable resources are currently exploited in the industrialized nations of Asia (Australia, Japan, and New Zealand) varies substantially. In New Zealand, for example, more than two-thirds of the country's electricity needs are met by renewable energy sources—mostly hydroelectricity and geothermal. In contrast, Australia meets most of its electricity demand with thermal generation, predominantly from coal; and in Japan almost all of the country's electricity is supplied from thermal sources and nuclear power. Hydroelectricity and other renewable energy consumption in the region is projected to grow by 1.7 percent per year between 2001 and 2025 (Figure 75), to 12 percent of the region's total energy use in the electric power sector by 2025.

Japan

With an electricity market dominated by thermal and nuclear generation, the growth in Japan's renewable energy resources has been fairly slow. Fossil fuels (oil, natural gas, and coal) account for 70 percent of Japan's total installed generating capacity and nuclear another 20 percent.

There have been some efforts by the Japanese government to increase the penetration of nonhydroelectric renewables in the country. The Law on Special Measures for Promotion of Utilization of New Energy (the New Energy Law), which entered into force in mid-1997, included provisions to encourage the development of wind-powered electricity generation in the country [**94**]. Japan ratified the Kyoto Protocol in 2002. If the Protocol enters into force, Japan will be required to reduce its output of greenhouse gases by 6 percent relative to its 1990 emissions level between 2008 and 2012. These developments may provide an opportunity for increased development of the country's renewable energy sources. Indeed, although Japan's wind capacity increased by only 31 megawatts between 1989 and 1998, its installed wind capacity grew by nearly 40 megawatts in 1999, by 50 megawatts in 2000, and by another 40 megawatts in 2001.

Australia

The Australian government introduced the Mandated Renewable Energy Target in 2001, decreeing that electricity retailers and large power purchases must increase the renewable share of their electricity mix by an additional 2 percent before 2010 [**95**]. The Renewable Energy (Electricity) Act of 2000 specifies a number of interim yearly targets over the 2001-2020 time period. As a result of the new legislation, wind energy projects are receiving new interest, and a number of wind projects were either planned or under construction in 2002. In August, the Victoria state government approved the Australian company Pacific Hydro's plans for developing a 180-megawatt wind farm at Portland [**96**]. In November, Pacific Hydro also confirmed its plans to construct a 100-megawatt wind project in northwest Tasmania [**97**]. Another Pacific Hydro wind project is currently under construction at Challicum Hills, near Ararat [**98**]. The 53-megawatt wind facility is expected to cost an estimated $76 million and is scheduled for completion by mid-2003.

Several other companies are entering the Australian wind market. The New Zealand electricity generator and retailer Trustpower has announced plans to construct a 60-megawatt wind project near Myponga on the Fleurieu peninsula of South Australia [**99**], which will be the company's first venture in Australia. The startup of construction on the $55 million project is pending approval from the state Development Assessment Commission. A second 35-megawatt wind project is already being built by Australia's Tarong Energy on the Fleurieu peninsula at Starfish Hill. Tarong received government approval for the project in April 2002. The $36 million project is scheduled to begin operating in April 2003.

The Indian-based company Ausker Energies is developing the Tungketta wind project, which is to be constructed on the Eyre peninsula of South Australia [**100**]. The first phase of the project will consist of 49.5 megawatts of wind capacity, with subsequent phases that could increase capacity to between 115 and 200 megawatts.

There are also several projects under consideration for New South Wales. Australian energy developer Michelago is planning to construct a 30-megawatt wind project near Goulburn in the Southern Highlands region of New South Wales. In addition, Wind Corporation of Australia has proposed building a $14 million, 20-megawatt wind project at Black Springs near Oberon [**101**].

New Zealand

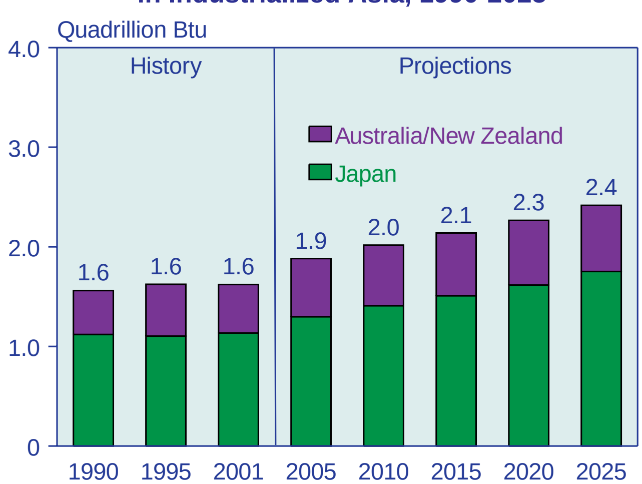
New Zealand has already extensively exploited its renewable energy resources. The country relies on renewable energy sources, particularly hydroelectricity, for nearly 70 percent of its total electricity supply [**102**]. Geothermal energy sources in New Zealand are also widely established, and installed geothermal capacity has grown by 54 percent over the past decade, reaching 437 megawatts in 2000, according to the Geothermal Energy Association [**103**].

Development of New Zealand's wind power resources has been lackluster by comparison. At the end of 2001, slightly more than 35 megawatts of wind capacity had been installed at three sites, the latest of which became operational in 1999 [**104**]. There is some hope that the release of the government's National Energy Efficiency and Conservation Strategy, which calls for increasing the renewable share of total energy supply by an additional 19 percent (to 42 percent) by 2012, will help spur an increase in wind-generated electricity.

Africa/Middle East

For the most part, hydroelectricity and other renewable energy resources have not been widely exploited in Africa or the Middle East. Most of the hydroelectric power projects in the Middle East are located in Turkey and Iran. In Africa, the largest installed hydroelectric capacities are in Egypt and Congo (Kinshasa). Several African countries—including Ivory Coast, Kenya, and Zimbabwe—rely almost exclusively on hydropower for commercial electricity generation; however, it is because

Figure 75. Renewable Energy Consumption in Industrialized Asia, 1990-2025



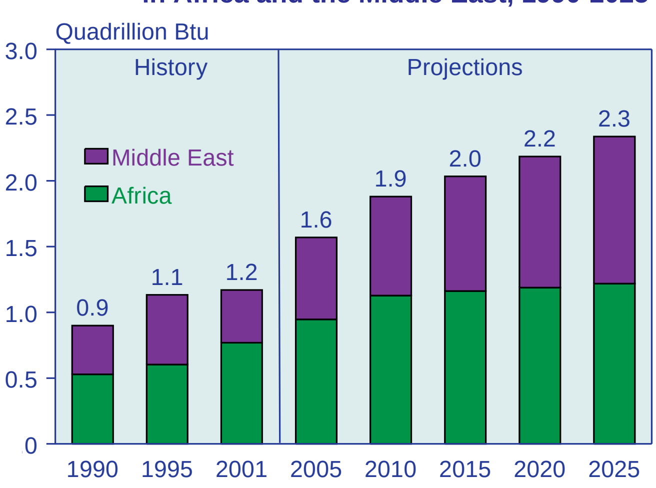
Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2003).

of the absence of an electricity infrastructure in these and many other African countries rather than the presence of an extensive hydroelectric system. Other, nonhydroelectric renewable energy resources are also used in Africa and the Middle East, primarily to serve small, rural communities that are not served by national electric power grids. Renewable energy consumption in Africa and the Middle East is expected to increase from 1.2 quadrillion Btu in 2001 to 2.3 quadrillion Btu in 2025 (Figure 76).

For many nations in Africa, future hydroelectric projects may depend on the ability to attract investment dollars. Because large-scale hydroelectric projects are often controversial, many traditional funding sources for hydropower development—particularly, the World Bank but also many import-export banks that are needed by developers to guarantee loans in areas that have a high risk of defaulting on agreements—have increasingly decided against providing financial aid to governments that wish to pursue them.

One example of the hesitancy of international financing sources to fund hydroelectric power projects is the 200-megawatt Bujagali Dam at the Bujagali Falls on the Nile River in Uganda. U.S.-based AES Corporation announced plans to construct the $550 million project in 1994 [***105***] and by December 2001 had secured funding commitments from the World Bank, International Finance Corporation, African Development Bank, Wesdeutsche Landesbank Girozentrale, and Australia and New Zealand Banking Group Limited, with export credit guarantees obtained from several European Banks. The argument for lending financial support to the construction of the Bujagali Dam was that the electricity was desperately needed in a country where less than 5 percent of the populace has access to electricity. However, international environmental groups have countered that the project would submerge a number of local cultural sites and displace more than 90 households [***106***]. In June 2002, with allegations of corruption surrounding the bidding process for Bujagali, the World Bank postponed its decision to approve $250 million in loan guarantees. The Ugandan government has vowed to continue with the project, but no schedule has yet been announced for the 4-year effort.

Figure 76. Renewable Energy Consumption in Africa and the Middle East, 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 (2003).

Similar problems have beset the Sondu Miriu hydroelectric project in Kenya. Originally conceived in 1985 as a multiple-purpose system of dams, the project was substantially scaled back, and in 1989 the Kenya Power Company, Ltd. (now the Kenya Electricity Generating Company, Ltd., or KenGen) obtained funding from the Japanese government [***107***]. Funding for the first phase of the $150 million project was provided in 1997, and construction on the 60-megawatt dam began with an original completion date of March 2003 [***108***]. Concerns over human rights violations and the impact of the project on the environment led the Japanese Bank for International Cooperation to delay releasing funds for the second phase of the project, however, and now completion is not expected before 2005 [***109***].

It took some 13 years to complete the 200-megawatt Manantali hydroelectric project in southwestern Mali, adding transmission lines to the hydropower project that had been completed in 1987. Funding problems and disputes among the three countries—Mali, Senegal, and Mauritania—that share the Senegal River, where the project is located, delayed completion of the project. By some estimates the project cost almost $1 billion—far more than the original budget. Funding to complete the project was finally provided by the World Bank and other international donors in 2002, and it was scheduled to begin supplying electricity to the three countries involved by the end of 2002. Electricity from the project is to go to Mali (52 percent), Mauritania (15 percent), and Senegal (33 percent), with plans to expand electricity exports to other West African countries, including Togo, Benin, and Ghana.

Several other hydropower projects are either planned or under construction in Africa. Construction of the 300-megawatt Tekeze hydroelectric project in Ethiopia began in 2002 [***110***]. The $224 million project is the largest African joint venture with China; the China National Water Resources and Hydropower Engineering Corporation is building the 607-foot dam, which will be higher than China's own Three Gorges Dam. The project, expected to be completed by 2007, will supply both electricity and water for irrigation to large parts of northern Ethiopia.

Construction continued on the Lesotho Highlands Water Project in the southern African kingdom of Lesotho. The project has received $106 million from the World Bank for completion, including a 72-megawatt hydroelectric station as one part of the system [111]. The project has faced delays, mostly because of corruption allegations and issues surrounding the resettlement agreement with the population to be affected by the construction of a reservoir, but in October 2002 the impoundment of the Mohale Reservoir started, marking the final step of construction in the first phase of the water project [112].

Mozambique plans to construct the Mepanda Uncua hydroelectric project, which will be located about 45 miles downstream from the existing 3,750-megawatt Cahora Bassa dam on the Zambezi River [113]. Much of the output from Cahora Bassa is exported to South Africa and Zimbabwe, and with growing demand for electricity Mozambique believes that the new Mepanda Uncua project will be essential for the country to meet its needs. The cost of the project has been estimated at $1.8 billion. The construction is two be completed in two phases, adding 1,300 megawatts in the first phase and another 1,100 megawatts in the second phase. The government is currently pursuing potential investors for the project and plans to begin construction in 2005.

Sudan is also pressing forward with plans to construct the Hamdab hydroelectric dam in Merowe, about 250 miles north of Khartoum [114]. The 1,250-megawatt project, which would triple electricity generation in Sudan, would take 6 years to complete. In 2002 the Sudanese government began the process of accepting bids for construction of Hamdab; however, it is unclear when construction might actually begin, given the economic disrepair of the country, which has suffered from a 19-year civil war.

Some nonhydroelectric renewable energy projects are also advancing in Africa. Egypt, for instance, has become the largest wind-generating country in the region and predicted that its installed wind power capacity could increase to 150 megawatts in 2002 [115]. The country's New and Renewable Energy Authority has undertaken the construction of a 60-megawatt wind farm at Za'farana in northern Egypt. The Egyptian government has stated its intention to change all oil-fired power plants to natural gas and is also looking at the potential for solar and wind generation to supplement electricity supplies. Morocco is also considered one of the more important markets for wind generation in Africa. The country has installed multiple wind projects, ranging from a few kilowatts up to 50 megawatts in size [116].

There is growing interest in the potential for alternative renewable energy markets in Africa. For instance, in July 2002 the Chinese-based company Shenzhen Topway Solar announced its intention to transfer its manufacturing base to Africa [117], stating that the move was desirable because the region is currently considering locating its base either in Nairobi (Kenya) or Kampala (Uganda) before 2004. The company currently supplies solar products to 15 African countries.

In the Middle East, hydroelectric development is centered primarily in Turkey. There area already more than 100 hydroelectric plants operating in the country, contributing 11,000 megawatts of the total Turkish installed electric capacity of 26,000 megawatts. The country has plans to continue developing its hydroelectric resources. It is currently constructing the massive Southeast Anatolia Project (called "GAP"), which includes portions for hydroelectric generation and irrigation [118]. The $32 billion project includes 21 dams and 19 hydroelectric plants that will add around 7,500 megawatts of installed generating capacity upon completion.

The largest dams to be constructed as part of GAP include the 2,400-megawatt Ataturk, the 1,800-megawatt Karakaya, and the 1,200-megawatt Ilisu. When completed, Ilisu would be the largest hydroelectric project on the Tigris River. British civil engineering company Balfour Beatty withdrew from the Ilisu project in November 2001 when the UK Export Credit Guarantee Department indicated that it would withdraw its support for the dam under considerable pressure concerning the impact the dam would have both on the environment and on the people who would have to be relocated to construct Ilisu [119]. More than 60,000 people, mostly ethnic Kurds, would be displaced by the construction. In a similar development, the British engineering company AMEC decided in March 2002 to withdraw from the Yusefeli dam project in Turkey [120]. The company denied that it had withdrawn because of the experience of Balfour Beatty, citing its conclusion that the project would not yield sufficient returns to justify AMEC's continued participation.

Several hydroelectric projects are moving forward in Turkey. In 1998, the United States and Turkey signed a joint statement on hydroelectric development that includes provisions for construction of nine dams [121], including the $337 million Alpasian II to be constructed on the Murat River in eastern Turkey. The U.S. company Earth Tech signed a contract with the State Hydraulic Works of Turkey for the design phase of the 200-megawatt project, which will include an irrigation component.

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Electricity

Electricity consumption nearly doubles in the IEO2003 projections. Developing nations in Asia and in Central and South America are expected to lead the increase in world electricity use.

In the *International Energy Outlook 2003* (*IEO2003*) reference case, worldwide electricity consumption is projected to increase at an average annual rate of 2.4 percent from 2001 to 2025 (Table 22 and Figure 77). The most rapid projected growth in electricity use by region is 3.7 percent per year for developing Asia, where robust economic growth is expected to increase demand for electricity to run newly purchased home appliances for air conditioning, refrigeration, cooking, and space and water heating. By 2025, developing Asia as a whole is expected to consume almost 2.5 times as much electricity as it did in 2001. In China, electricity consumption is projected to grow by an average of 4.3 percent per year, nearly tripling over the forecast period.

In Central and South America, as in developing Asia, high rates of economic growth are expected to improve standards of living and increase electricity use for industrial processes and in homes and businesses. The expected growth rate for electricity use in Central and South America is 3.3 percent per year. In Brazil, the region's largest economy and largest consumer of electricity, electricity consumption is projected to increase by 3.2 percent per year, with electrification coming to rural populations that previously have not had access to the national grid.

Electricity consumption in the industrialized world is expected to grow at a more modest pace than in the developing world, at 1.7 percent per year. In addition to expected slower growth in population and economic activity in the industrialized nations, market saturation and efficiency gains for some electronic appliances are expected to slow the growth of electricity consumption from historical rates.

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, 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 resulting from the OPEC oil embargo of 1973-1974 and

Table 22. World Net Electricity Consumption by Region, 1990-2025
(Billion Kilowatthours)

Region	History 1990	History 2001	Projections 2005	Projections 2010	Projections 2015	Projections 2020	Projections 2025	Average Annual Percent Change, 2001-20205
Industrialized Countries	**6,368**	**8,016**	**8,307**	**9,200**	**10,106**	**11,030**	**11,994**	**1.7**
United States	2,827	3,602	3,684	4,101	4,481	4,850	5,252	1.6
EE/FSU	**1,906**	**1,528**	**1,768**	**1,982**	**2,204**	**2,423**	**2,642**	**2.3**
Developing Countries	**2,272**	**4,390**	**4,886**	**5,962**	**7,172**	**8,555**	**10,038**	**3.5**
Developing Asia	1,259	2,730	3,103	3,851	4,697	5,634	6,604	3.7
China	551	1,312	1,545	1,966	2,428	2,986	3,596	4.3
India	257	497	528	662	802	958	1,104	3.4
South Korea	93	270	296	372	443	498	552	3.0
Other Developing Asia	358	650	734	850	1,024	1,192	1,352	3.1
Central and South America	463	721	782	925	1,081	1,302	1,577	3.3
Total World	**10,546**	**13,934**	**14,960**	**17,144**	**19,482**	**22,009**	**24,673**	**2.4**

Note: EE/FSU = Eastern Europe and the 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, System for the Analysis of Global Energy Markets (2003).

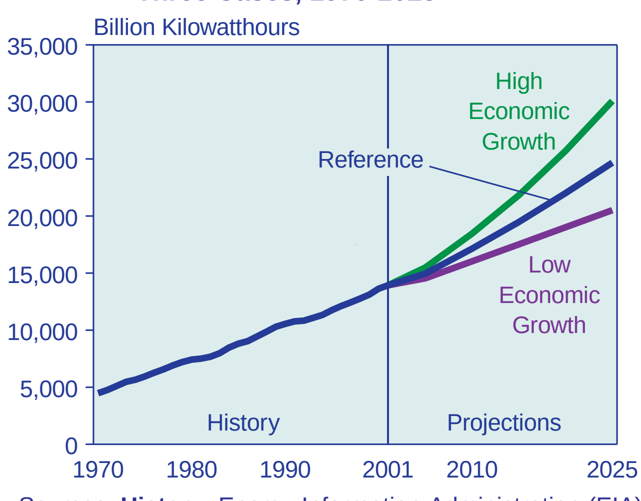
the Iranian Revolution of 1979, the use of oil for electricity generation has been slowing since the mid-1970s.

In the *IEO2003* 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 diminished somewhat by the 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 and few new reactors are expected to replace them. Generation from hydropower and other renewable energy sources is projected to grow by 56 percent over the next 24 years, but their share of total electricity generation is projected to remain near the current level of 21 percent.

Natural Gas

Electricity markets of the future are expected to depend increasingly on natural-gas-fired generation. Industrialized nations are intent upon using 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 almost 2.5 times greater in 2025 than it was in 2001 (Table 23), 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, particularly in Central and South America, where heavy reliance on hydroelectric power has led to shortages and blackouts during periods of severe drought.

Figure 77. World Net Electricity Consumption 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:** EIA, System for the Analysis of Global Energy Markets (2003).

The former Soviet Union (FSU) accounted for more than one-third of natural gas usage for electricity generation worldwide in 2001, and natural gas provided 42 percent of the energy used for electricity generation in the FSU. By 2025, natural gas is projected to account for 63 percent of the electricity generation market in the FSU. Relying increasingly on imports from Russia, the nations of Eastern Europe are also expected to increase their use of natural gas for electricity generation, from a 9-percent share of total generation in 2001 to 50 percent in 2025.

In North America, the natural gas share of the electricity fuel market in the United States is projected to increase from 18 percent in 2001 to 24 percent in 2025, with Canadian exports expected to provide a growing supply of natural gas to U.S. generators. The natural gas share of electricity generation in Canada is also projected to grow, from 3 percent in 2001 to 11 percent in 2025.

Natural gas consumption for electricity generation in Western Europe is projected to nearly triple over the forecast period, and its share of the region's electricity fuel market is projected to grow from 17 percent in 2001 to 38 percent in 2025 as the nuclear power and coal shares are reduced. After the oil crisis of 1973, European nations actively discouraged the use of natural gas for electricity generation (as did the United States) and instead favored domestic coal and nuclear power over dependence on natural gas imports. In 1975 a European Union (EU) directive restricted the use of natural gas in new power plants. The natural gas share of the electricity market in Western Europe fell from 9 percent in 1977 to 5 percent in 1981, where it remained for most of the 1980s. In the early 1990s, the growing availability of reserves from the North Sea and increased imports from Russia and North Africa lessened concerns about gas supply in the region, and the EU directive was repealed.

In Central and South America natural gas accounted for 9 percent of the electricity fuel market in 2001. Its share is projected to grow to 46 percent in 2025. Hydropower is the major source of electricity supply in South America at present, but environmental concerns, cost overruns on large hydropower projects in the past, and electricity shortfalls during periods of drought have prompted South American governments to view natural gas as a means of diversifying their electricity supplies. A continent-wide natural gas pipeline system is being built in South America, which will transport Argentine and Bolivian gas to Chile and Brazil.

Per capita consumption of natural gas in Asia and Africa is relatively small when compared with Europe and North America. In 2001, Japan accounted for one-fourth of natural gas consumption in Asia. Almost all natural gas consumed in Japan is imported as liquefied natural gas (LNG). Japan is expected to maintain its dependence on natural gas at around 20 percent of the electricity fuel market through 2025.

Coal

In 2025, coal is expected to account for 31 percent of the world's electricity fuel market, slightly lower than its 34-percent share in 2001. The United States accounted for 40 percent of all coal use for electricity generation in 2001, and China and India together accounted for 27 percent. In the *IEO2003* forecast, the coal share of U.S. electricity generation is expected to remain at roughly 50 percent through 2025. China's coal share is projected to rise slightly, to 73 percent in 2025 from 72 percent in 2001. Over the same period, coal's share of India's electricity market is expected to decline from 72 percent to 63 percent. Although coal remains a relatively cheap source of electricity production, natural gas is viewed as being environmentally superior, and the economics of natural gas generation technology are improving, particularly in countries with access to gas pipelines.

Reliance on coal for electricity generation is also expected to be reduced in other regions. In Western Europe, for example, coal accounted for 20 percent of the electricity fuel market in 2001 but is projected to have only a 12-percent share in 2025. Similarly, in Eastern Europe and the FSU (EE/FSU), coal's 27-percent share of the electricity fuel market in 2001 is projected to fall to 6 percent in 2025. For years, massive state subsidies were all that kept many coal mines operating in Western and Eastern Europe. In many cases, the subsidies were underwritten by electricity consumers. The EU has adopted policy measures to eliminate or reduce state subsidies for domestic coal production, and only four EU member states (the United Kingdom, Germany, Spain, and France) continue to produce hard coal.

Nuclear Power

The nuclear share of energy use for electricity production is expected to decline in most regions of the world as a result of public opposition, waste disposal issues,

Table 23. World Energy Consumption for Electricity Generation by Region and Fuel, 2000-2025
(Quadrillion Btu)

Region and Fuel	History		Projections				
	2000	2001	2005	2010	2015	2020	2025
Industrialized	**89.0**	**89.6**	**92.1**	**99.9**	**106.4**	**113.3**	**120.1**
Oil	5.0	4.9	4.5	4.6	5.0	5.2	5.5
Natural Gas	14.3	14.7	16.6	19.4	23.5	28.4	33.5
Coal	30.5	30.9	32.3	34.8	35.4	36.1	37.7
Nuclear	22.6	22.4	21.6	22.3	22.4	21.9	20.4
Renewables	16.5	16.7	17.2	18.9	20.0	21.7	23.0
EE/FSU	**23.2**	**22.6**	**20.6**	**22.8**	**25.3**	**26.3**	**27.0**
Oil	1.5	1.3	0.4	0.5	0.9	1.2	0.8
Natural Gas	7.9	8.0	8.5	9.5	12.0	13.7	16.1
Coal	6.3	6.0	4.9	4.1	3.6	2.7	1.6
Nuclear	4.3	4.1	3.2	3.3	3.3	3.0	2.6
Renewables	3.2	3.2	3.6	5.5	5.6	5.7	5.8
Developing	**39.8**	**41.2**	**47.0**	**55.0**	**64.1**	**74.1**	**85.0**
Oil	5.0	5.3	6.2	6.0	6.8	7.6	8.2
Natural Gas	6.3	6.5	7.2	9.8	13.4	16.7	21.0
Coal	14.4	15.1	18.1	21.4	23.8	28.3	32.7
Nuclear	2.6	2.7	2.7	3.1	4.2	4.5	5.0
Renewables	11.4	11.7	12.8	14.6	15.9	17.0	18.0
Total World	**151.9**	**153.4**	**159.7**	**177.7**	**195.7**	**213.7**	**232.0**
Oil	11.6	11.5	11.1	11.1	12.7	14.0	14.5
Natural Gas	28.4	29.2	32.3	38.7	48.8	58.9	70.6
Coal	51.2	52.0	55.2	60.3	62.9	67.1	72.0
Nuclear	29.5	29.1	27.5	28.7	29.8	29.4	28.0
Renewables	31.1	31.6	33.5	38.9	41.5	44.4	46.9

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

Sources: **History:** Derived from International energy Agency, *Energy Statistics of OECD Countries 1999-2000* (Paris, France, 2002), and *Energy Statistics of Non-OECD Countries* (Paris, France, 2002). **Projections:** EIA, System for the Analysis of Global Energy Markets (2003).

concerns about nuclear arms proliferation, and the economics of nuclear power. The nuclear share of electricity generation worldwide is projected to drop to 12 percent in 2025 from 19 percent in 2001.

In the United States, the nuclear share is projected to decline from 19 percent of the electricity fuel market in 2001 (second behind coal) to 15 percent in 2025. In Canada, where the nuclear share of the market has been declining since 1984, its 22-percent share in 2001 is projected to fall to 11 percent in 2025. In Western Europe, where Finland is the only country projected to build new nuclear units, the nuclear share of the region's electricity fuel market is projected to fall from 34 percent in 2001—more than any other energy source—to 21 percent in 2025.

In Japan, nuclear power accounted for 39 percent of the energy used for electricity generation in 2001. That share is expected to decline to 31 percent by 2025 in the *IEO2003* forecast. In the EE/FSU region, the nuclear share is projected to decline from 18 percent in 2001 to 10 percent in 2025.

Nuclear power contributes very little to electricity generation in the developing nations of Central and South America, Africa, and the Middle East, and it is expected to contribute little in 2025. In Central and South America, only Argentina and Brazil were nuclear power producers in 2001. In Africa, only South Africa generated electricity from nuclear power in 2001. There are no nuclear power plants in operation in the Middle East, although two are under construction in Iran.

In contrast to the rest of the world's regions, in developing Asia nuclear power is expected to play a growing role in electricity generation. China, India, Pakistan, South Korea, and Taiwan currently have nuclear power programs, and the nuclear share of the region's electricity fuel market is expected to remain stable at roughly 9 percent from 2001 through 2025. China is expected to account for most of the region's nuclear power capacity additions.

Hydroelectricity and Other Renewables

Renewable energy, predominantly hydropower, accounted for one-fifth of the world's energy use for electricity generation in 2001, where it is expected to remain through 2025. Of the world's consumption of renewable energy for electricity production in 2001, the United States and Canada together accounted for almost 29 percent of the total, Western Europe for 20 percent, and Central and South America 19 percent (despite consuming just 5 percent of the world's electricity).

In 2001, renewables accounted for 9 percent of electricity production in the United States and 56 percent in Canada, both nations where hydroelectric power has been extensively developed. Their shares are expected to grow slightly by 2025. In North America and throughout the world, generation technologies using nonhydroelectric renewables are expected to improve over the forecast period, but they still are expected to be relatively expensive in the low price environment assumed for energy fuels in the *IEO2003* reference case.

Hydroelectricity is used the most for electricity generation in Central and South America, and renewables accounted for 73 percent of the region's electricity fuel market in 2001. Recent experiences with drought, cost overruns, and the negative environmental impacts of several large-scale hydroelectric projects have reduced the appeal of hydropower in South America, however, and the renewable share of electricity generation in the region is expected to decline to 45 percent by 2025 as countries work to diversify their electricity fuel mix.

Most of Western Europe's renewable energy consumption consists of hydroelectricity. Renewables in total accounted for 24 percent of the region's electricity market in 2001, and their share is expected to increase to 25 percent in 2025. Some European nations, particularly Denmark and Germany, are actively developing their nonhydroelectric renewable energy resources, most notably wind.

Some near-term growth in renewable energy use is expected in developing Asia, particularly in China, where the 18,200-megawatt Three Gorges Dam and a number of other major hydropower projects are expected to become operational during the forecast period. Developing Asia relied on renewables for 18 percent of its electricity production in 2001, and that share is expected to shrink slightly, to 16 percent in 2025.

Oil

The role of oil in the world's electricity generation market has been on the decline since the 1979 oil price shock. Oil accounted for 23 percent of electricity fuel use in 1977; in 2001 its share stood at 7 percent. Energy security concerns, as well as environmental considerations, have already led most nations to reduce their use of oil for electricity generation. In regions where oil continues to hold a significant share of the generation fuel market, such as the FSU and the Middle East, it generally is expected to maintain its position. As a result, the oil share of world energy use for electricity production is projected to remain stable at between 6 and 7 percent through 2025.

Developing Asia accounted for 18 percent of the world's consumption of oil for electricity generation in 2001, when 7 percent of its electricity fuel use consisted of oil (down from 29 percent in 1977). The oil share of electricity fuel consumption in developing Asia is expected to remain stable through 2025. In the petroleum-rich

Middle East, oil supplied 38 percent of the energy used for electricity generation in 2001, and its share is projected to decline slightly, to 34 percent in 2025.

Foreign Investment in Electricity

In the mid- to late 1990s, a massive amount of U.S. capital crossed oceans to acquire electricity assets. Those mergers and acquisitions gave rise to the multinational electricity company. U.S. capital investment targeted nations and regions that were engaged in electricity reforms, which often included privatization and removal of restrictions on foreign investment. Major targets included South America, Australia, and the United Kingdom. Large amounts of non-U.S. foreign capital also flowed into those electricity markets, particularly from Europe.

Over the past few years, the flow of foreign capital into South American electricity ventures has stalled. The same is true of the outflow of U.S. capital into Western Europe and Australia. The slowdown was in part caused by the sluggish state of the global economy and a reduction in international capital flows[24] in general [***1***], as well as the disappointing financial performance of many earlier electricity acquisitions. U.S. companies in particular have retreated from several markets which they quickly grew to dominate in the late 1990s, such as Australia and the United Kingdom, in many instances citing disappointing financial results as a cause for the departure.

Domestically, the United States saw a major wave of mergers and acquisitions in electricity through much of the 1990s, giving rise to electricity producers with a national presence. Some mergers and acquisitions also involved more vertical integration among energy companies. Several involved both natural gas and electricity producers, leading to a greater convergence between electricity fuel producers and electricity generators. U.S. mergers and acquisitions peaked in 1999, however, and have since slowed to a trickle. During the 1990s many mergers and acquisitions were financed through equity swaps. The weakness in equity markets for roughly the past 2 years may have forestalled further consolidation of the U.S. electricity industry.

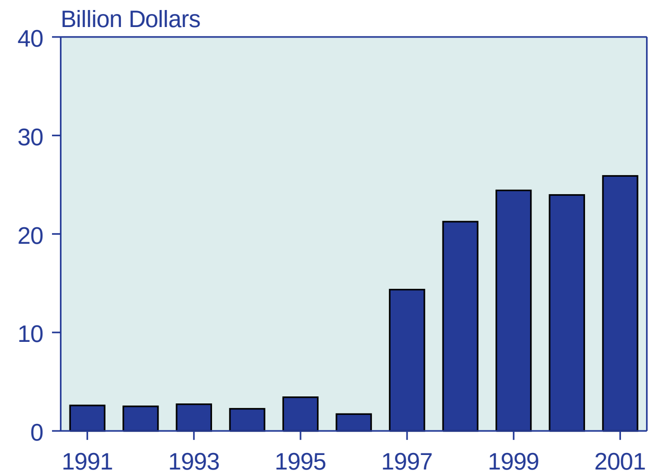
Many developing countries, particularly in Asia and South America, opened their electricity sectors to private capital, much of which came from overseas investors, in the 1990s. Growing foreign investment provided an important source of capital for the construction of new generating capacity to meet rapidly growing electricity demand. Those investments peaked in 1997, and by 2001 they were only about one-fifth of their 1997 levels.

In contrast, continental Europe has only recently seen a wave of merger and investment activity, both internally and across borders. In 1996, the then 15 members of the EU adopted an electricity directive, which became effective in 1997 [***2***]. The goal of the directive was to establish a single European electricity market. Recent merger and acquisition activities on the continent suggest that the market is moving in that direction as far as ownership goes.

United States

Financial flows from the United States into electricity assets overseas leveled between 1999 and 2001 (Figure 78). Among developed countries, a large share of the flow of U.S. overseas investment during the mid-1990s was to the United Kingdom, shortly after the country's 12 distribution companies were privatized and its electricity market was opened to foreign investment (Table 24). The first U.S. acquisition in the UK electricity sector was in 1995, when Southern Company and PP&L Resources purchased the distribution company SWEB (formerly South Western Electricity). Of the 12 UK distribution companies, 8 were purchased by U.S.-based

Figure 78. U.S. Direct Investment in Overseas Utilities, 1991-2001



Note: The utility investments shown include, in addition to electricity, natural gas distribution and sanitary services; however, the sharp rise in investments from 1996 to 1999 is largely the result of investments in overseas electric utilities by U.S. companies.

Source: U.S. Department of Commerce, Bureau of Economic Analysis, *Survey of Current Business* (Washington, DC, various issues).

[24]For foreign investment this chapter looks at the absolute stock of investment in overseas utilities. This stock represents the net effect of both outflows and inflows. The foreign direct investment (FDI) position is the cumulative net flow of funds between a foreign-affiliated company and its foreign owners. The U.S. Department of Commerce, the agency that collects data on FDI, measures FDI as the book value of foreign direct investors' equity in, and net outstanding loans to, their U.S. affiliates. The Commerce Department defines a U.S. affiliate as a U.S. business enterprise in which one foreign direct investor owns 10 percent or more of the voting securities or the equivalent.

utilities. Since the mid-1990s, however, French and German utilities have supplanted U.S. companies in the UK market. U.S. utilities have sold 5 of their UK distribution companies since 1998.

Figure 79 shows U.S. investment flows into the utility sectors of Australia, Brazil, and the United Kingdom.[25] In recent years U.S. investment in UK and Australian electricity concerns has waned. The U.S. foreign direct

Table 24. Mergers and Acquisitions in UK Electricity

Company	Current Owners	Date of Acquisition
Regional Distribution and Supply Companies		
UK Companies Purchased by Foreigners		
Eastern Group	Texas Utilities	1998
Midlands Electricity	Avon Energy Partners	1996
Northern Electric and Gas	CalEnergy	1996
SEEBOARD	Central and South West Corporation	1996
SWEB	Southern Company & PP&L Resources	1995
Yorkshire Electricity	American Electric Power and New Century Energies	1997
London Electricity	Entergy	1996
Yorkshire Electricity	American Electric Power & PS Colorado	1996
UK Companies Sold to UK Owners		
East Midlands Electricity	PowerGen	1998
Manweb	Scottish Power	1995
Norweb	North West Water	1995
Southern Electric	Scottish Hydro-Electric (merger)	1998
SWALEC	Welsh Water	1996
SWALEC (Supply)	British Energy	1999
Yorkshire Electricity	Innogy (UK)	2001
Yorkshire Electricity	Northern Electric	2001
Midlands Electricity (Supply)	National Power	1998
UK Companies Sold to European Owners		
London Electricity	Electricité de France	1998
SWEB (Supply)	London Electricity	1999
Northern Electric	Berkshire Hathaway (U.S.) and RWE (German)	1999
Norweb	E.ON (German)	2002
SEEBOARD	Electricité de France	2002
Generation and Transmission Companies		
UK Companies Purchased by Foreigners		
PowerGen	E.ON	2001
Eastern Electricity	Electricité de France	2002
SWEB[a]	Electricité de France	1999
U.S. Companies Purchased by or Merged with UK Companies		
LG&E	PowerGen	2000
Various generation assets	International Power	—[b]
New England Electric System	National Grid Company	1999
Pacificorp	Scottish Energy	1999
AmerGen[c]	British Energy	1999

[a]Electricité de France purchased SWEB's customer supply business.
[b]International Power had 4,000 megawatts of capacity in operation in the United States in late 2002. Source: International Power Corporation, web site www.ipplc.com.
[c]AmerGen is a joint venture between British Energy and its U.S. partner Exelon.
Source: UK Electricity Association, News Releases (1998-2003), web site www.electricity.org.uk.

[25]Most of the investment shown was in electric utilities; however, the data source did not separate electric utilities from other utilities, such as natural gas and sanitary.

investment position in South American utilities may also have peaked, although the data have yet to indicate it.

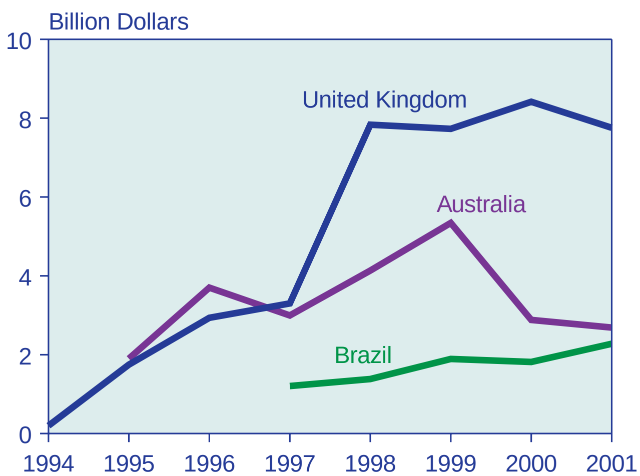
In many cases, U.S. companies paid a premium for their overseas utility acquisitions and may not have been able to realize expected returns. In the United Kingdom, for example, unexpected regulatory interventions led to a considerable drop in earnings for U.S. companies invested in UK electricity distribution companies [***3***]. In South America, economic recession and currency fluctuations made repayment of interest and principal on loans used to acquire electricity assets exceedingly difficult. Further, some South American countries have been reluctant to allow utilities to raise prices in order to recoup increased fuel costs and capital and interest costs [***4***]. A new political horizon appears to be emerging in much of South America with the election of several new governments in recent years. As a result, in the near term, little if any new foreign investment capital is expected to flow into South American electricity ventures.

Total investment in U.S. utilities by foreign companies also increased dramatically during the late 1990s (Figure 80). Although trailing the wave of U.S. investment in electricity overseas by about 2 years, foreign companies had invested roughly as much in U.S. utilities by 2000 as U.S.-based companies had invested overseas. By far the largest share of foreign investment in U.S. utilities has come from the United Kingdom. The largest foreign-owned acquisition of a U.S. utility thus far has been Scottish Power's purchase of PacifiCorp of Oregon for $12.9 billion. Other important transactions include the purchase of LG&E by the United Kingdom's PowerGen for $5.4 billion in 2000; the purchase of New England Electric System by UK's National Grid Company's for $3.2 billion in 2000; and British Energy's joint venture with U.S.-based Exelon to form AmerGen.

In the mid- to late 1990s, there was also a wave of domestic mergers and acquisitions in the U.S. electricity sector (Figure 81). By 2000 the trend had started to slow. Only five announcements were made in 2001, and by mid--year 2002 only one announcement had been made. Measured by announcement, domestic mergers and acquisitions among U.S. electricity companies reached a peak of 26 in 1999.

Several factors drove the U.S. electricity industry retrenchment: falling stock prices and the difficulties that posed in capital formation [***5***, ***6***]; a slowdown in domestic economic growth; the fallout the entire industry experienced as a result of the financial scandal surrounding Enron and other energy companies; and the recent spate of overbuilds during the late 1990s and early 2000s. The collapse of the U.S. electricity merger and acquisition market can be traced in part to the poor financial performance of the industry since 1999. Overexpansion in the late 1990s and early 2000s may have been one cause for the lack of activity as the U.S.

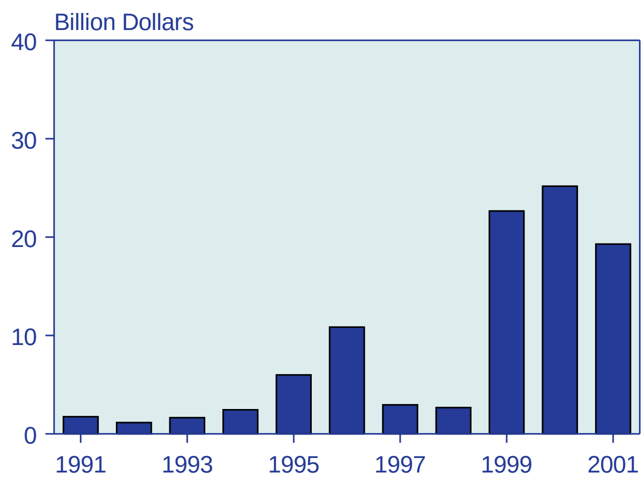
Figure 79. U.S. Direct Investment in Australian, Brazilian, and United Kingdom Utilities, 1994-2001



Notes: The utility investments shown include, in addition to electricity, natural gas distribution and sanitary services; however, the sharp rise in investments in 1994 and 1999 is largely the result of investments in overseas electric utilities by U.S. companies. For some years, data were not made available for U.S. investments in Brazil and Australia due to the Commerce Department's disclosure rules regarding individual companies.

Source: U.S. Department of Commerce, Bureau of Economic Analysis, *Survey of Current Business* (Washington, DC, various issues).

Figure 80. Foreign Direct Investment in U.S. Utilities, 1991-2001



Note: The utility investments shown include, in addition to electricity, natural gas distribution and sanitary services; however, the sharp rise in investments during the late 1990s is largely the result of investments in U.S. electric utilities by foreign companies.

Source: U.S. Department of Commerce, Bureau of Economic Analysis, *Survey of Current Business* (Washington, DC, various issues).

economy fell into recession just as a number of new capacity builds came on line. Between 2000 and 2002, 133,457 megawatts of capacity were added to the U.S. electrical grid, four times the amount of capacity brought on during the previous 5 years [*7*]. In the process of this expansion, electricity companies amassed unusually high debt loads, making further expansion in the face of weakened economic growth doubtful. Between 1998 and 2001, the fixed-income debt of electric utilities more than doubled [*8*].

Hurt worst by falling stock prices were those companies that diversified most from their core utility businesses. Some companies have exited the nascent business of electricity trading, and others have sold off assets acquired domestically and overseas [*9*]. Several companies have seen their share prices plummet and their debt downgraded to junk status [*10*]. According to a Standard and Poor report, during the first 9 months of 2002, 135 debt downgrades of electric utility holding companies took place, roughly four times the number during the same period a year earlier [*11*]. The report also noted that 11 percent of the companies surveyed were rated below investment grade.

In the late 1990s and early 2000s, much of the construction or acquisition of electricity generation assets was financed by short-term debt, which has exposed several companies to severe financial difficulties in 2003. It has been estimated that utilities would need to refinance $50 billion in debt in early 2003. Utility financial health may continue to deteriorate over the next several years if the gap between available margins and utilized margins widens. Fears of future overcapacity have led to the cancellation of several power plants planned for completion during 2003 and 2004 [*12*]. The Energy Information Administration forecasts growth in reserve margins from 16 percent in 2001 to 18 percent in 2004 [*13*].

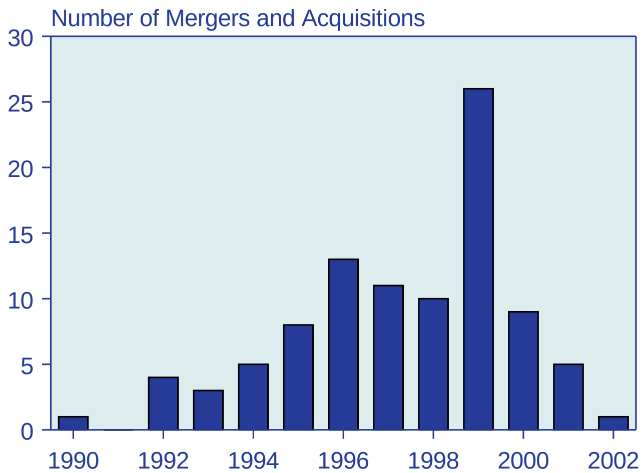
Developing Countries

Developing nations are projected to consume 5,648 billion more megawatthours of commercial electricity in 2025 than in 2001 (see Table 22). An important element in that consumption growth will be investment spending needed for the developing world's electricity generation capacity to keep pace with future demand. Many developing nations have ambitious goals to expand their electricity infrastructure over the coming decades. Some plans may prove feasible and others not. A major concern over whether developing countries can meet their goals is how readily capital will become available to fund needed investments.

Foreign investment in electricity, both private and noncommercial, has played a growing role in many nations' electricity sectors over the past decade (Figure 82 and Table 25). In developing countries, after peaking at $49 billion in 1997, private investment in electricity projects dropped to $10 billion in 2001, roughly equal to the level in 1992, when foreign investment in electricity in developing nations first took off.

By region, however, private capital investment differs in several ways. In some countries, foreign investment has been restricted to new capacity additions, or primarily to new electric power generation. This has generally been true of Asia. In other countries, foreign investment has been free to acquiring existing assets, e.g., a state-owned

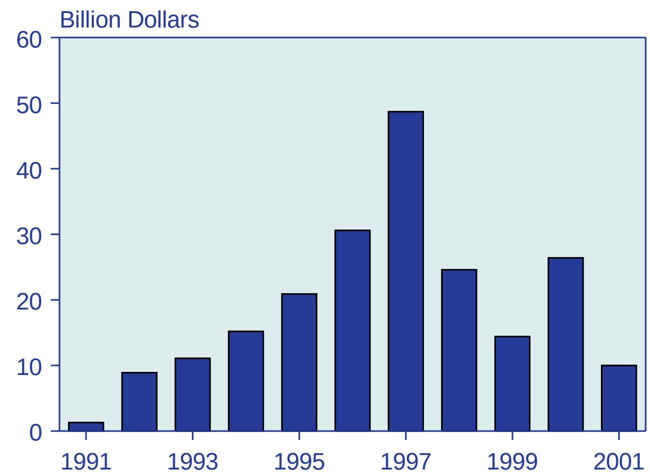
Figure 81. Mergers and Acquisitions in the U.S. Electricity Industry, 1990-2002



Note: Data for 2002 cover the period from January through July.

Source: Edison Electric Institute, "Mergers and Acquisitions" (December 31, 2002), web site www.eei.org/issues/finan/fininfo/021231ma.xls.

Figure 82. Private Sector Investment in Electricity Projects in Developing Countries, 1991-2001



Source: World Bank Group, Private Sector and Infrastructure Network, *Public Policy for the Private Sector*, Note Number 246, "Private Infrastructure" (June 2002), web site http://rru.worldbank.org/viewpoint/.

electricity distribution company, as has generally been the case in South America. In general, most private investment capital has been in generation, which accounted for four-fifths of total electricity investment in the years 1990-1999 [***14***].

Investment in electricity projects in the developing world showed substantial growth through most of the 1990s, followed by a decline with the onset of the Asian economic crisis in 1997. Economic growth in developing Asia has rebounded, along with private investment in electricity projects, but investment in private-sector electricity projects in Latin America has not yet recovered, in part because of the region's weak economic performance in recent years.

Foreign capital comes from a variety of commercial and noncommercial sectors. Depending on the nation, reliance on foreign capital to finance electricity projects varies considerably. The sources of capital also vary from nation to nation, and countries frequently rely on a diversity of resources for major electricity infrastructure investment. Lenders may include multinational global institutions (such as the World Bank and the Asian Development Bank), publicly held entities, foreign government loans (such as from the U.S. Export/Import Bank), quasi-national organizations (such as Japan's Overseas Development Fund), and commercial bank loans. In addition, several developing nations have chosen to acquire listings on foreign stock exchanges [***15***].

Western Europe

In Western Europe, electricity has traditionally been supplied by state-owned national monopolies. Since the implementation of the European Electricity Directive, which became law in 1997,[26] there has been a sharp acceleration of cross-border mergers and acquisitions in Western European electricity markets [***16***]. Unlike the mergers and acquisitions in the UK electricity sector, which were largely made by U.S. utilities, those in Western Europe have typically involved other European firms, with U.S. companies playing a minor role. In 2000 and 2001 there were 35 mergers and acquisitions in Western Europe, compared with 15 in 1998 and 1999 (Figure 83).

Table 25. Private Sector Investment in Electricity Projects in Developing Regions, 1990-2000
(Million Dollars)

Country Group	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Investment in Greenfield Electricity Projects by Region											
Sub-Saharan Africa	—	—	—	—	76	3	395	209	115	325	—
EAP	—	250	2,063	4,622	5,501	5,640	9,920	12,064	5,031	668	2,321
ECA	68	—	650	—	—	1,760	1,392	194	231	221	—
LAC	206	—	245	327	1,279	2,737	1,908	2,829	2,784	2,484	7,292
MENA	—	—	—	—	205	—	—	60	—	898	826
South Asia	135	614	32	1,048	2,078	2,546	3,780	1,486	1,147	2,311	3,357
Investment in Privatized Electricity Projects by Region											
Sub-Saharan Africa	—	—	—	—	—	—	580	274	601	150	30
EAP	44	129	1,315	171	1,499	1,151	1,313	1,246	120	1,593	1,923
ECA	—	—	246	—	1,210	1,388	1,980	1,903	276	465	821
LAC	759	19	1,907	2,640	1,316	2,748	6,840	18,314	10,958	4,285	6,029
MENA	—	—	—	—	—	—	—	—	—	—	—
South Asia	—	—	—	3	—	—	1,047	—	144	49	47
Total											
Sub-Saharan Africa	—	—	—	—	76	3	975	483	716	475	30
EAP	44	379	3,378	4,793	7,000	6,791	11,234	13,310	5,151	2,261	4,244
ECA	68	—	896	—	1,210	3,148	3,373	2,096	507	687	821
LAC	964	19	2,152	2,967	2,594	5,486	8,748	21,143	13,743	7,134	13,321
MENA	—	—	—	—	205	—	—	60	—	898	826
South Asia	135	614	32	1,051	2,078	2,546	4,827	1,486	1,291	2,359	3,404

EAP = East Asia and Pacific, ECA = Europe and Central Asia, LAC = Latin America & the Caribbean, MENA = Middle East and North Africa. For definitions of country groups, see World Bank, "Country Classification," web site www.worldbank.org/data/countryclass/classgroups.htm.

Source: Public Policy for the Private Sector, World Bank Data Base, web site www.worldbank.org.

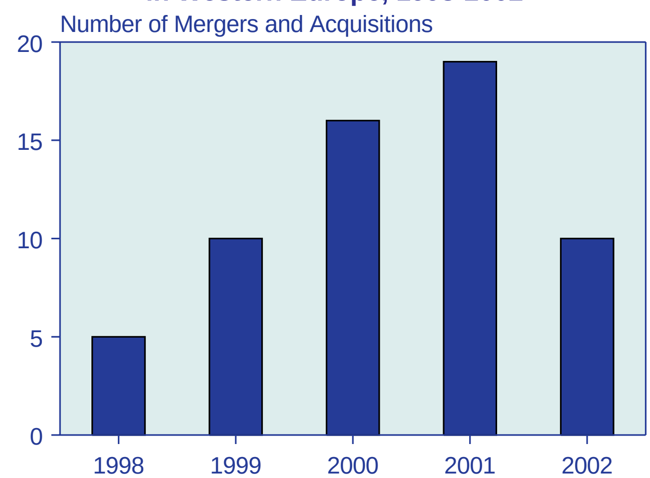
[26]The European Electricity Directive became effective in February 1997. It called for the 15 EU member nations to open at least 26 percent of their national markets to competition by February 1999, expanding to 30 percent in 2000 and 35 percent by 2003. The Directive established uniform rules for all aspects of electricity supply and called for the unbundling of generation, transmission, and distribution.

Among European nations, Germany has seen the most activity, much of which has involved German companies purchasing other German companies. Between 1998 and 2002 there were 23 mergers in the German electricity sector [17]. The largest of all European mergers involved E.ON, Germany's second largest electric power producer, and Ruhrgas, Germany's largest natural gas producer [18]. Western Europe's electricity sector is increasingly being dominated by a handful of multinationals, and growth in electricity trade has paralleled the continent's electricity industry consolidation. Between 1999 and 2000, electricity trade in Western Europe grew by 13 percent, compared with an average annual increase of 4 percent for the 1990-2000 period [19].

E.ON has clearly joined the ranks of multinational utilities, with subsidiaries in the Czech Republic, Denmark, Hungary, Italy, Lithuania, the Netherlands, Norway, Poland, Sweden, the United Kingdom, and the United States. In purchasing the United Kingdom's PowerGen, E.ON became the second largest provider of electricity to the UK market and owner of Kentucky-based utility LG&E. Some other European electric utilities have also extended their activities across the globe. Electricité de France, for instance, reported in its 2001 annual report a customer base of 43 million in 22 countries [20]. The United Kingdom's International Power, in addition to its domestic operations, had in mid-2002 operations in the United States, the Czech Republic, Portugal, Spain, Turkey, Australia, China, Malaysia, Oman, Pakistan, Thailand, and the United Arab Emirates [21].

Only a handful of the 15 EU members have been targets of foreign electricity investment, depending on their openness to market liberalization and other reform. Table 26 shows a number of indicators estimating the relative openness of selected EU countries' electricity sectors, as reported in an analysis sponsored by the UK Department of Trade and Industry and the government of the Netherlands. The table addresses several concepts of "openness." First is openness in the "competitive" arena, which was evaluated by two measures: (1) upstream market and wholesale competition, involving electricity generation, and (2) downstream market competition, involving the ability of customers to switch suppliers and the number of new entries into the supply market. In both the upstream and downstream measures of openness in the "competitive" segment of the industry, Norway, the United Kingdom, the Netherlands, and Germany rank much higher than France, Italy, and Spain. Second is openness in "noncompetitive areas," involving such factors as the degree of fair and open access to the transmission grid and regulatory independence. In these areas, the United Kingdom, Norway, and the Netherlands rank relatively high, but Italy ranks higher than Germany. As a result of their relative openness, levels of concentration in the electricity markets of the United Kingdom, the Netherlands, Germany,

Figure 83. Cross-Border Mergers and Acquisitions in Western Europe, 1998-2002



Source: Centre d'Économie Industrielle Ecole Nationale Superérieure des Mines de Paris, "Mergers and Acquisitions in the European Electricity Sector, Cases and Patterns" (August 2002), p. 115.

Table 26. Liberalization Indicators for Selected European Electricity Markets (Index)[a]

Market Area	France	Germany	Italy	Netherlands	Norway	Spain	United Kingdom
Competition-Related Areas							
Upstream and Wholesale Market Competition	1.7	6.7	3.9	8.3	8.9	4.8	9.0
Downstream and Competition and Customer Benefits	1.8	5.4	3.0	4.1	8.2	3.8	7.6
Overall Competition Indicator	1.7	6.0	3.4	6.2	8.5	4.3	8.3
Noncompetitive Areas							
Network Access and Ownership	4.8	5.8	7.8	7.8	10.0	6.8	9.0
Regulatory Influence	1.7	1.7	6.7	6.7	8.3	1.7	6.7
Overall Noncompetition Indicator	4.0	4.7	7.5	7.5	9.6	5.5	8.4

[a]Index of liberalization, where 1 is the lowest value and 10 is the highest value.

Source: Oxford Economic Research Associates, *Energy Liberalisation Indicators in Europe* (London, UK: Department of Trade and Industry, October 2000), Table 2.5, p. 36, web site www.dti.gov.uk/energy/gas_and_electricity/international_policy/oxera_report.pdf.

and Norway have lessened considerably in recent years in comparison with those in other European countries (Table 27).

World Electricity Deregulation

Since the early 1980s, several nations have experimented with various models of electricity reform.[27] Some have worked reasonably well, others have not, and nations considering reform have closely watched other nations' experiments. Over the past several years, some of the developments that prevailed in global electricity markets in the 1990s appear to have stalled or, in some cases, moved backward. In India, electricity sector reforms have been introduced but then have had to be adjusted when they have failed to produce the intended results (see box on page 146). It still seems likely, however, that nations, states, and regions will continue with electricity sector reforms. Indeed, both South Korea and Mexico are moving ahead aggressively (see box on page 150); and U.S. States like Pennsylvania and Texas have launched relatively successful restructuring programs (see box on page 151). Disappointing results in some markets are expected to be brought into better perspective in the future as more reform efforts prove successful and past mistakes are avoided.

Three notable examples of reforms that have failed to live up to expectations are the restructuring programs in California, England and Wales (the UK model),[28] and Ontario. Although the California and UK experiences involved a host of different reforms, from dealing with stranded costs to implementing retail competition, where both efforts failed notably was in the implementation of competitive electricity trading arrangements—particularly in California. In Ontario, reforms did not fail to meet expectations so much as they were rejected by the public due to summer heat-related price shocks that came about when some prices were decontrolled.

To the extent that regulatory reform in electricity has been successful, it has often been emulated elsewhere. To the extent that nations have viewed their reform efforts as failed, in some cases modifications have come about; in others, reregulation has been introduced. Although various degrees of reregulation have been introduced elsewhere, including in New Zealand and several Eastern European countries [***22***], probably nowhere has the retreat from electricity reform been so dramatic as in California.

California

In designing its electricity reform model, California borrowed several elements from the UK model, including a requirement that all sales be made through a daily pool. In the California Power Exchange (PX), the pool price was determined in the following manner: the PX created an electricity supply and demand curve by combining

Table 27. Concentration in European Electricity Markets, 1999-2000

Country	Company and Market Share								
France	EDF	Other							
	80%	20%							
Germany	RWE Ag	PE	Other						
	21%	15%	64%						
Italy	ENEL SpA	Other							
	80%	20%							
The Netherlands	EPON	EPZ	UNA	EZH	Other				
	30%	21%	17%	13%	19%				
Norway	Statkraft	Norsk Hydro	Oslo Energy	Other					
	31%	12%	6%	51%					
United Kingdom	National Power	PowerGen	British Energy	Eastern Group	East Midlands Electricity	AES	Magnox Electric	Imports	Other
	19%	16%	11%	11%	9%	6%	5%	5%	18%

Source: L. Birnbaum, C. Grobbel, P. Ninios, T. Röthel, and A. Volpin, "A Shopper's Guide to Electricity Assets in Europe," *The McKinsey Quarterly*, 2000 Number 2: Europe, pp. 60-67, web site www.hgreene.com/other/mckweb/energy/shgu00.asp.

[27]Chile is generally regarded as the nation that led the current wave of wholesale electricity reform (which started in Chile during the early 1980s).

[28]Electricity reforms on England and Wales are widely referred to as UK reforms. Although the United Kingdom includes Northern Ireland and Scotland, which have embarked on separate reform efforts, what has become known as the "UK model" refers to developments in England and Wales. The UK model involved separating the four sectors of electricity supply (generation, transmission, distribution, and marketing) by ownership and by function and the implementation of a competitive electricity trading arrangement for the competitive elements of the electricity market. It also involved retail competition. For transmission and distribution, a performance-based price formula was employed, indexed to the general rate of inflation and a productivity factor. This regulatory scheme became known as RPI-X.

Electricity Reform in India

Electricity reform activities in India have increased markedly in the past decade. Reforms have been spurred by the underlying need for access to affordable, reliable electricity. India's Planning Commission estimated in the Ninth Five Year Plan (1997-2002) that additional generation capacity 40,245 megawatts would be needed to meet the government's goal of 8-percent growth in gross domestic product (GDP); however, only 19,015 megawatts of additional capacity was added.[a] The shortfall in capacity growth can be attributed to economic and technical inefficiencies in the power sector structure. A financially strong sector is needed to increase generation capacity, renovate and modernize current plants, and increase coverage and access of power service.

The poor financial health of the power sector can be attributed mainly to electricity tariffs that do not accurately reflect the cost of providing electricity service. Average revenues from the power sector are lower than the average cost of producing power. Although tariffs for the commercial and industrial sectors are set higher then their fully allocated costs, they are not high enough to offset the subsidy inherent in residential and agricultural rates. Tariffs have been influenced by political considerations. For example, many of the agricultural subsidies stemmed from the Green Revolution of the 1980s, when certain political parties used populist measures to win elections, such as offering lower tariff rates to support farmers.[b]

Another factor affecting the financial solvency of the sector is transmission and distribution (T&D) losses. T&D losses are estimated at 30 to 50 percent, which are considerably higher than those of other developing nations, such as China (7 percent) and Indonesia (12 percent).[c] T&D losses consist of both technical losses (15 to 20 percent), such as transmission line loss, and nontechnical losses (20 to 25 percent), such as theft. In addition, low billing and collection efficiency has contributed to the mounting financial insolvency of the state electricity utilities. These losses translate into commercial losses of almost $3 billion[d] or financial losses equal to nearly 1 percent of the national GDP. This is a major drain on the Indian economy, amounting to twice what the government spends on health and one-half of what it spends on education.[e]

According to the Indian constitution, the power sector is treated as a multijurisdictional entity, where both the central and state governments have jurisdiction. This has resulted in a division of activities such as policymaking, planning, financing, and operating between the state and central governments. The Ministry of Power oversees power policy at the federal level and receives guidance from the Planning Commission. The Central Electricity Authority (CEA) provides technical analysis and approval of power projects. Several public sector corporations operate generation, transmission, and rural electrification and handle financial issues surrounding those activities.

After gaining independence from the British in 1947, the government of India enacted the Electricity Supply Act of 1948. The 1948 Act brought all new power generation, transmission, and distribution under the responsibility of the public sector, especially at the state level. As a result, each state and union territory established State Electricity Boards (SEBs), vertically integrated entities that were funded by the state governments. By the early 1990s, the SEBs controlled 70 percent[f] of the generation, most of the transmission lines, and a majority of the distribution.

After sustaining a closed economy since independence, India experienced a balance of payments crisis in the early 1990s. As part of an effort to liberalize the economy, an amendment was made to the 1948 Electricity Supply Act, called the Electricity Laws (Amendment) Act of 1991. One purpose of the legislation was to encourage private investment in power generation through eight "fast track" projects. Independent power producers were invited to build power plants with incentives from the central government, including speedier technical, economic, and environmental clearances by the CEA, as well as counter-guarantees[g] by

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[a]Planning Commission, Government of India, *Tenth Five Year Plan (2002-2007)*, Vol. 2, Chapter 8, "8.2. Power," p. 897, web site http://planningcommission.nic.in/plans/planrel/fiveyr/10th/volume2/v2_ch8_2.pdf (Draft, 2003).

[b]N.K. Dubash and S.C. Rajan, "The Politics of Power Sector Reform in India" (World Resources Institute, April 2, 2001), web site http://pdf.wri.org/india.pdf.

[c]World Bank and Public-Private Infrastructure Advisory Facility, *India: Country Framework Report for Private Participation in Infrastructure* (Washington, DC, March 2000), web site http://lnweb18.worldbank.org/sar/sa.nsf/Attachments/infras/$File/Report.pdf.

[d]World Bank and Public-Private Infrastructure Advisory Facility, *India: Country Framework Report for Private Participation in Infrastructure* (Washington, DC, March 2000).

[e]E.R. Lim, Address to the World Bank Conference on Distribution Reforms (October 12-13, 2001), web site http://lnweb18.worldbank.org/SAR/sa.nsf/Attachments/engy/$File/Limpower.pdf.

[f]N.K. Dubash and S.C. Rajan, "The Politics of Power Sector Reform in India" (World Resources Institute, April 2, 2001).

[g]Counter-guarantees are guarantees by the Central government to cover the dues owed to the IPPs if the state government is not able to cover them.

Electricity Reform in India (Continued)

the government of India, a guaranteed 16-percent return on equity, and tax holidays.

The Mega-Power Policy was later introduced, with special incentives for construction and operation of thermal plants over 1,000 megawatts and hydro plants over 500 megawatts. By the end of 1993, more than 140 applications had been received for 70,000 megawatts of capacity, but by 1995-96, despite enthusiastic response to the private power policy, no projects had been initiated on the ground. Of the eight fast-track projects to which the best possible terms had been offered, none was near financial closure.[h] The most controversial and highly-publicized of the fast track projects, U.S. Enron's Dabhol power project, exemplified the many issues that were hindering growth of power generation: financial insolvency of the SEBs, political interference, lack of transparent regulatory structure, and other inefficiencies in the system.

Because of the failure of the fast track projects and the slow progress of state-level reforms, the central government acknowledged the need for more comprehensive reforms at the national level. In 1998, the central government passed the Electricity Regulatory Commission Ordinance (ERC) establishing the Central Electricity Regulatory Commission (CERC) and encouraging the establishment of State Electricity Regulatory Commissions (SERCs). CERC would be responsible for regulating tariffs of centrally owned utilities, regulating interstate transmission, providing guidelines for tariff setting to SERCs, and handling disputes between generation and transmission entities. The SERCs would be able to set tariffs, procure and purchase power, and promote competition and more efficient operations.

In 2000, the Electricity Bill was introduced to the Indian parliament as a piece of comprehensive legislation to replace all other electricity legislation. The bill has seen several incarnations while awaiting passage. The Electricity Bill consists of the such measures as generation free from licensing (except for hydro units), mandatory establishment of state-level regulatory commissions, open access for transmission and distribution, and retail tariff setting by the regulatory commissions. The Ministry of Power developed a "Blueprint for Power Sector Development" in the spring of 2001, in which power sector reform was outlined.

As discussed in the Blueprint, distribution reform is a crucial component of the reform process, which has been addressed in recent reform legislation and activity. The central government is financially supporting distribution reform through the Accelerated Power Development Reforms Programme (APDRP). Thirty-five billion rupees ($700 million) was appropriated in the 2002-2003 Union Budget for the APDRP to support 63 distribution circles. Distribution circles are an attempt to disaggregate state monitoring operations to small, manageable "profit centers," which would be responsible and accountable for their losses. The distribution circles will implement full metering, energy audits, management information systems, control of theft, increased transformation capacity, increases in the ratio of high-voltage to low-voltage transmission (it is more difficult to steal electricity from a high-voltage line), and reduction of technical losses.

Reforms at the state and union territory level began long before the central government provided an umbrella framework for power sector reform. Several states—Haryana, Orissa, and Andhra Pradesh—were encouraged by the World Bank to undertake structural reforms in their power sectors to maintain funding for power projects through Adaptable Program Loans.[i] Most states have established electricity regulatory commissions in an effort to move toward cost-based prices. Some states and union territories have unbundled their SEBs into separate units for generation, transmission, and distribution.

The process of corporatization and privatization has been much slower than other reform activities, as seen in the state of Orissa electricity reform experiment. Orissa has been at the forefront of India's state-initiated reform efforts with the World Bank playing a role in promoting, financing, and guiding the reforms. The World Bank canceled financial assistance of $156 million to Orissa for the Upper Indravati Hydroelectric Project in 1991 because of slow progress and lack of satisfaction with contracts awarded[j] and announced that it would reissue the assistance only if Orissa would reform its electricity sector.[k] In 1993, the World Bank converted some of the funds from the canceled hydro project to provide assistance to the state government's electricity reform program.

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[h]Tata Energy Research Institute, *Electrifying Reforms in the State Electricity Boards* (April 2000), web site www.teriin.org/energy/seb.htm.

[i]The World Bank Group, "Adaptable Loans: World Bank Meets Changing Demands," web site http://web.worldbank.org (Feature Story, November 20, 1997).

[j]T.A. Rajan, "Power Sector Reform in Orissa: An Ex-post Analysis of the Causal Factors, *Energy Policy*, Vol. 28 (2000), pp. 657-669.

[k]T.A. Rajan, "Power Sector Reform in Orissa: An Ex-post Analysis of the Causal Factors, *Energy Policy*, Vol. 28 (2000), pp. 657-669.

Electricity Reform in India (Continued)

In 1995, the Orissa Electricity Reform Act was enacted to support several actions. The first was the establishment of an Electricity Regulatory Commission, which was entrusted with tariff setting as well as acting as an independent regulatory body. The Orissa State Electricity Board was unbundled into state-owned companies: GRIDCO to handle transmission and distribution, Orissa Power Generation Corporation, and Orissa Hydro Power Corporation. It also allowed for private investment in generation. In 1997, privatization of the distribution sector commenced through the establishment of distribution companies. The state was divided into four geographic distribution zones, which were bid out to various private entities. Bombay Suburban Electric Supply (BSES) bought three of the zones and the U.S. firm AES bought the fourth.

Each of these actions was implemented in Orissa with mixed levels of success. One of the conditions set by the World Bank was to reduce the levels of T&D loss. However, due to a lack of accurate information on T&D losses, the distribution companies were given underestimated T&D loss values. Their loss reduction targets were based on the initial estimates, but once metering and other technologies were installed, the real loss values were ascertained to be much higher (see table).

State-Level Transmission and Distribution Losses

State	Reported T&D Losses (Percent) Pre-reform Reporting	Reported T&D Losses (Percent) Post-reform Reporting
Orissa	23	51
Andhra Pradesh	25	45
Haryana	32	47
Rajasthan	26	43

Source: Ministry of Power, Government of India, *Blueprint for Power Sector Development* (2001).

Furthermore, several financial matters proved troubling. Because the SEB was already in poor financial shape, it was difficult to attract potential buyers in the bidding process and spur competition. Competition was also curbed by the reintroduction of horizontal and vertical integration. BSES, an electricity supplier, controlled three of the four distribution zones and AES, operating the fourth, was also heavily involved with generation in Orissa. As a result, private investors found it difficult to estimate the risks involved in participating in the newly reformed electricity sector. One of the risks was estimating revenues from the retail tariff, because the pricing system was based on an annual tariff hearing. The process of divestiture of assets to the private sector was also contentious: undervaluing the assets was perceived to be "giving them away" to the private firm; overvaluing the assets would increase the pricing of tariffs and thus increase retail prices.[l]

Delhi, a union territory, has also recently embarked on power sector reform. There is confidence in the Delhi model, which builds on the experience in Orissa and must only contend with an urban setting versus the much more dispersed rural setting. After the ERC Act in 1998, Delhi instituted the Delhi Electricity Regulatory Commission (DERC). The Delhi Vidyut Board (former electricity board) was unbundled and privatized in 1999. Based on lessons learned in Orissa, the privatization of the Delhi electricity board dealt with the issue of asset valuation, developed a new method for estimating financial risk from T&D loss, and also changed the system of bidding for distribution companies.[m]

The regulatory commission in Delhi is using a business valuation of the assets (based on the future earning potential) to avoid overvaluation. DERC has also been responsible for estimating the level of aggregate technical and commercial losses (AT&C)[n] and then setting the loss level for the bidding process.[o] Selection of bidders for the three distribution companies is based on the maximum reduction of AT&C loss over a 5-year period. (In contrast, in Orissa, the highest bidder for a 51-percent equity stake in the company was awarded the contract.)[p] Furthermore, in Delhi the distribution companies will be able to realize a 16-percent rate of return on equity only if the minimum loss reductions are met.[q] Subsidies will not be removed immediately as they were in Orissa. Instead, the territorial government has acknowledged the need for transition period measures.

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[l]L.C. Gupta and C.P. Gupta, *Financing Infrastructure Development: A Holistic Approach with Special Reference to the Power Sector* (Delhi: Society for Capital Market Research and Development, November 2001).

[m]"Power Sector Reforms and Privatization of Distribution in Delhi." Presentation by the Delhi Electricity Regulatory Commission for the Power Mission Conference (October 2002).

[n]AT&C loss includes T&D losses and collection efficiency and is defined as 1- [(billing in units / input in units) x (collection in Rupees / billing in Rupees)]. Source: 3iNetwork, *India Infrastructure Report 2003: Governance Issues for Commercialization* (Delhi: Oxford University Press, 2003), web site www.3inetwork.org / reports / IIR2003 / iir_report_content.html.

[o]Delhi Electricity Regulatory Commission, "Commission's Orders," web site www.dercind.org.

[p]3iNetwork, *India Infrastructure Report 2003: Governance Issues for Commercialization* (Delhi: Oxford University Press, 2003), web site www.3inetwork.org / reports / IIR2003 / iir_report_content.html.

[q]K. Ramanathan and S. Hasan, *Privatization of Electricity Distribution: The Orissa Experience* (New Delhi: Tata Energy Research Institute, 2003).

Electricity Reform in India (Continued)

As India's experiment in power sector reform unfolds, it remains to be seen whether Delhi will be able to internalize the issues highlighted in the Orissa privatization process. If Delhi can construct a profitable model, other states (all in different stages of the reform process) may also adopt similar methodologies and work toward a more financially viable power sector. Financial solvency of the state electricity entities may create a better investment climate for the power sector in both generation and distribution. A financially sound power sector could aid in the infrastructure development needed to support economic growth in India and other much needed services for the public.

all generator supply bids with all consumer demand bids. The clearing price (the price paid to generators by suppliers) was determined by the intersection of the supply and demand curves. This was similar to the pricing scheme initially employed in the United Kingdom, except that in the United Kingdom demand was estimated by the National Grid Company. What distinguished the California Pool was the separation of the California Independent System Operator (CAISO) from the PX. Moreover, California reforms did not provide pool participants with the hedging opportunities that the "contracts for differences" market provided in the United Kingdom. UK electricity suppliers made extensive use of such contracts, which greatly reduced their exposure to price fluctuations. The contracts for differences market allowed UK generators to hedge between 80 and 90 percent of their exposure in the day-ahead market [***23***].

Several structural flaws have been identified in California's restructured market following the State's electricity crisis. One was the requirement that California utilities purchase all their power through the PX; another was the prevention of purchasing power in a forward market that forced California utilities to buy short for their long–term electricity supply contracts; another was the degree to which the California market encouraged competition. Energy companies and energy traders have admitted to trying to manipulate the California energy market during the electricity crisis, and others have been accused of doing so by the Federal Government [***24***]. One method of manipulation involved the fee that companies could earn by reducing load on voltage lines that were overburdened. Companies have been accused of wrongfully creating congestion on paper where no congestion actually occurred. In order to do this, companies simply needed to schedule electricity to be sent over lines where the nominated values would cause congestion, even though they had no intention of actually using the lines. This act alone could result in the company being compensated for providing no service at all.

In May 2002, the U.S. Federal Energy Regulatory Commission (FERC) released Enron internal corporate memos that suggested that Enron was scheming the California energy market by creating phantom congestion and then being compensated for alleviating that congestion, and by moving electricity in and out of the State to avoid price caps. In July 2002, the FERC claimed further that Enron overcharged customers in California for natural gas. And in August 2002, the FERC commenced an investigation to see whether three companies sought to control supply in the California market and thus create a runup in prices and profits. In November 2002, Williams Companies agreed to pay $400 million to settle accusations that it had gamed the West Coast electricity market and to restructure a $4.3 billion long-term electricity contract with California, whereby the State plans to save $1 billion [***25***].

In July 2002, several companies had reached a settlement with the State government to reimburse the State for a portion of the profits they earned during the energy crisis. The California State government was seeking $21 billion of the $43 billion in long-term contracts the State signed in 2001, claiming that the contracts were signed when the companies exercised illegal control over the California electricity market [***26***]. In March 2003, FERC staff recommended that the Commission issue "show cause" orders to companies that alledgedly violated California's trading rules. Under the show cause orders, companies would be held liable for the repayment of unfair profits unless they prove that their actions were justified [***27***].

The UK Model

In contrast to California's experience with electricity reform, the UK experience was largely successful, with the exception of introducing a satisfactory level of competition in the national pool. In early 2001, the United Kingdom shut down the pool, which had been in operation since 1990, and embarked on a new form of electricity trading system, called the New Electricity Trading Arrangement (NETA). This was done because it was felt that the old pool arrangements did not foster adequate competition. The initial pool setup was supposed to be the major arena in which competition was to be introduced in the UK electricity market [***28***]. However, even after the UK generation market was broken up during the mid-1990s, the UK pool was still highly concentrated.

The effort to instill more competition in the UK electricity pool involved policy changes that amounted to "fine tuning." The power pool was altered so that the clearing price became the bid price rather than the system marginal price as in the past. Further, generators were no longer forced to bid into the pool and were free to negotiate bilateral contracts.

The most commonly perceived failure of the old UK electricity pool was that bidding prices within the pool could easily be manipulated due to the small number of participants and to pool rules that were susceptible to manipulation through strategic bidding. Both auction theory and game theory come into play in trying to create a pool immune to such collusive behavior. In any event, since the initiation of the UK electricity pool in 1990, most of the efficiency gains realized through cost reductions at generation companies were not passed through to consumers. Despite generation costs falling by half, pool prices changed little after the inception of the electricity pool [**29**].

One feature of the UK pool that may have led to strategic bidding was the system marginal price. The way in which the UK electricity auction occurred was that generators bid into the system up to the point at which the bids provided enough capacity to clear demand as forecasted by the National Grid Company. The price bid on the last unit of capacity to clear the system became the system marginal price. This provided an incentive to manipulate the system by bidding in higher cost units in order to drive up the price, which is exactly what the major operators in the UK pool have frequently been accused of doing.

The major difference between NETA and the original pool is that the system marginal price, which was provided to all bidders who cleared the pool under the old system, was replaced by a pay-as-bid price. This was done so as to make market manipulation through strategic bidding less likely. Another significant difference is that NETA allows bilateral forward contracts. About 98 percent of electricity is now traded bilaterally [**30**]. NETA also allowed derivative trading, which provided another means of hedging exposure to price fluctuations.

NETA differs in several other important instances from the old UK electricity pool. NETA allows for self-dispatch instead of the National Grid Company performing the role of scheduler and orderer in addition to its role as a transmission provider, which made it the equivalent of the PX and CAISO combined. Under the old system, the responsibility of ensuring adequate electricity supply was entirely in the hands of the National Grid Company, which was responsible for forecasting electricity demand on a half-hourly basis for the following day. Under NETA, this responsibility was transferred to the generators themselves. Further, NETA opened up the wholesale market to non-generators, thus allowing commodity traders to participate in the market [**31**]. Unlike the old pool, NETA does not include a capacity mechanism.

Since NETA was implemented, electricity prices have fallen dramatically in the United Kingdom. However, a

South Korea and Mexico Press Ahead with Reforms

South Korea is one nation still moving ahead aggressively with electricity reform. A central element of the reforms is a dismantling of the state-owned utility, Kepco, along its functional units: generation, transmission, and distribution. The first phase of restructuring was scheduled for 2000, when Kepco was split into six individual companies: one nuclear and hydro company and five thermal power companies. The second phase of restructuring, which took place in 2000-2002, involved the creation of a market, a system operator, and an electricity pool. During the third phase, 2003-2009, regional distribution companies are scheduled for privatization.[a]

Mexico has also proceeded with electricity reform efforts. Mexican electricity reforms got started in 1992 with the passage of the Public Electricity Service Act, which allowed a limited opening of the electricity supply industry to non-government-owned entities. Private parties were allowed to participate in electricity generation, although they had to sell their power to the federal electricity commission. As a result of the Act, an independent electricity sector has emerged in Mexico, along with some foreign investment. The Mexican government has estimated that the nation will need $5 billion in electricity investment over the next 10 years. The president of Mexico hopes that private investors will add 30,000 megawatts of capacity over the next 10 years, which would nearly double Mexico's current capacity. The Act retained the monopoly of the Comisión Federal de Electricidad (CFE) as sole purchaser of electric power. After more than 2 years of debate, the Mexican Senate in November 2002 forwarded a legislation bill that would alter the Mexican constitution to allow private investment in electricity. The bill would also create separate generation, transmission, and distribution companies, create an independent system operator, and allow for the development of a merchant power industry.[b]

[a]M. Hutchinson and C.K. Liu, "South Korea's Managed Market Solution," *CERA's Asia Gas & Power Advisory Service* (April 11, 2003), web site www.cera.com.
[b]E. Malkin, "Mexico's Fox Proposes Opening Power Sectors," *The New York Times* (August 12, 2002), p. C4.

Successful Electricity Restructuring in Texas and Pennsylvania

Over the past decade, U.S. States have been exploring options for opening electricity markets to competition. Although California's restructuring failures are well documented, a number of States have had more successful electricity restructuring programs, and efforts to restructure electricity markets are continuing. Twenty-four States and the District of Columbia have enacted legislation that allows various levels of retail competition, and 18 States and the District of Columbia are actively implementing restructured retail markets. All are currently considered to be in the "transition" to competition. Pennsylvania and Texas provide two examples of what are generally regarded as successful restructuring programs, although both systems continue to be fine-tuned as issues arise.

"Successful competition" has been measured by such factors as the amount of load supplied by competitive suppliers, the level of sustained price decreases, and the ability to weather price spikes and / or support conditions that discourage frequent price spikes. Within the wholesale market, the ability to manage congestion, provide for competitive prices, and limit the ability of participants to exercise market control are considered important to maintaining a successful open market structure.

Pennsylvania's wholesale electricity market is controlled by the PJM Regional Transmission Organization (RTO), which operates in Pennsylvania, New Jersey, Maryland, Delaware, Washington, DC, and parts of Virginia and is widely recognized as the most successful U.S. RTO to date. PJM provides settlement of day-ahead and hourly prices, as well as energy scheduling and balancing for the Pennsylvania, New Jersey, Delaware and Maryland region, and agreements are in the works to coordinate and perhaps merge with other RTOs and power areas. PJM's system of locational marginal pricing is emerging as an effective way to manage congestion of the transmission grid through competitive prices.

Pennsylvania's reform efforts implemented several unique policy measures. For instance, the State initiated a shopping credit—a credit on the generation portion of a customer's bill to be used to pay a competitive provider. The customer would keep savings realized by choosing the competitive provider. This, coupled with a very humorous consumer education program, was credited for several years of success in inducing customer switching (almost one-quarter of the total State load at one point).

Pennsylvania has also led the development of a Mid-Atlantic model for uniform business practices.[a] Dramatic increases in natural gas prices in 2002, which led to substantial increases in U.S. electricity prices, diminished the competitiveness of some electricity suppliers. Many left the market, initiating a customer return to "providers of last resort"—suppliers designated for customers dropped by their competitive suppliers. After 2001, however, this service was provided not by incumbent utilities but by the suppliers that offered the best rates. For example, most customers of southwestern Pennsylvania's Duquesne Light finished paying stranded costs in March 2002, and now 27 percent of the electricity load in the territory is supplied competitively.[b] Even with the increase in natural gas prices, Pennsylvania's electricity prices have been reduced by about 8 percent (in real dollars) since restructuring legislation was enacted in 1996.

In Texas, full retail competition began on January 1, 2002, for customers in the Electric Reliability Council of Texas (ERCOT) RTO. Today, about 25 percent of demand in the ERCOT area is served by competitive suppliers.[c] In September 2001, utilities in Texas began the process of auctioning off part of their generating capacity. Restructuring legislation requires each generation company affiliated with a former monopoly utility to sell entitlements to at least 15 percent of its installed generation capacity at least 60 days before full retail competition begins.[d] Customers that require over 1.0 megawatts of generating capacity are not provided default service. In other words, they must choose a competitive service. Default and provider-of-last-resort services are provided at market rates.

The market in Texas differs from restructured markets in other States in that utilities are required to establish separate affiliates to provide retail service to customers, forcing distribution companies to stay out of retail marketing and generation. This has achieved a level of functional separation similar to the forced divestiture required by States such as Massachusetts. The Texas Public Utility Commission is working with ERCOT to explore transmission congestion and pricing reform, as well as demand response programs.

[a]Center for the Advancement of Energy Markets, *Electricity Retail Energy Deregulation Index 2001: For the United States, Canada, New Zealand, and Portions of Australia and the United Kingdom* (Washington, DC, April 2003), web site www.caem.org.
[b]Center for the Advancement of Energy Markets, *Electricity Retail Energy Deregulation Index 2001: For the United States, Canada, New Zealand, and Portions of Australia and the United Kingdom* (Washington, DC, April 2003), web site www.caem.org.
[c]Public Utility Commission of Texas, *Report to the 78th Texas Legislature: Scope of Competition in Electric Markets in Texas* (January 2003).
[d]Energy Information Administration, "Status of State Electric Industry Restructuring Activity as of February 2003," web site www.eia.doe.gov / cneaf / electricity / chg_str / texas.html (February 2003).

concern arising from NETA's initial success is that by driving electricity prices substantially lower, NETA will not remunerate electricity companies for investing in future power stations, thus guaranteeing future supply shortages and higher prices. The industry has called for a capacity mechanism to be put in place to ensure against future electricity shortages. Since March 2002, several generation companies have shut down capacity as a result of the low pool prices and have voiced concerns that NETA was at fault [***32***].

Devising trading arrangements suitable to a commodity with such unusual features as electricity has been an area that has dogged reformers in several countries, states, and provinces. Sharp price spikes are not new to pool-based electricity exchange systems. One concern that arose over California's recent experience with its electricity pool is whether suppliers under certain pool designs can achieve excessive market power. In countries that have adopted pool-based electricity trading systems, such as Canada, the United Kingdom, and Australia, similar concerns have arisen over the connection between price spikes and market power.

Ontario

Canada is another country that has backtracked somewhat in its electricity reform efforts. Since the early 1990s, some Canadian provinces have undertaken efforts at electricity reform. Most have involved modest changes, such as providing large users with the freedom to choose their electricity suppliers. Thus far, only Alberta and Ontario have embarked on wide-scale reforms.

Alberta was first in implementing electricity reform, a central feature of which was the initiation of an electricity pool. More recently, Ontario has introduced electricity reform efforts that include the creation of an electricity pool, dismantling of the former state-owned utility, future privatization, and consumer choice. One motivation behind Ontario's electricity reform was the unsatisfactory performance of the nuclear power plants operated by the previous public utility, Ontario Hydro [***33***].

When Ontario began restructuring its electricity industry, the province faced a number of issues, many of which had motivated electricity reform efforts elsewhere. In particular, Ontario's electricity provider at the time, Ontario Hydro [***34***], was viewed as inefficiently run, as having charged excessively high prices, and as having accumulated financially imprudent levels of debt. One indicator of the electricity sector's inefficiency was that Ontario Hydro's nuclear capacity factor averaged 80 percent in 1980-1983, fell to 70 percent in 1984-1989, and then fell to 65 percent in 1990-1996.

When electricity reform was being considered in Ontario, another justification was that several other nations and regions had already done it, and reforms were necessary to keep Ontario economically competitive. In several respects the reforms undertaken in Ontario resembled those in the United Kingdom, California, and elsewhere [***35***]. In 1997, the Ontario government developed a nine-point plan for dealing with several shortcomings in the province's electricity industry [***36***]. The plan was intended to:

- Create a competitive market in the year 2000 for both wholesale and retail customers
- Establish an Independent Market Operator and provide for an interim supply market for replacement power
- Separate monopoly operations from competitive businesses throughout the electricity sectors
- Provide the Ontario Energy Board with an expanded mandate to protect electricity consumers
- Take steps to ensure environmental protection
- Encourage cost savings in the local distribution sector
- Establish a level playing field on taxes and regulation
- Restructure Ontario Hydro into new companies with clear business mandates
- Take action to put the new electricity companies on a sound economic and financial footing.

The Energy Competition Act, which went into effect in 1998, did away with Ontario Hydro's monopoly in electricity supply [***37***]. Ontario Hydro was split into two successor companies: Ontario Power Generation, which assumed ownership of the generation assets of Ontario Hydro, and Hydro One, which assumed ownership of the transmission assets. The two companies began operating separately in April 1999. Three other entities were also created: an Independent Electricity Market Operator (IMO) similar to the CAISO in California; an Electrical Safety Authority (ESA); and an Ontario Electricity Financial Corporation (OEFC), which took on the multibillion-dollar debt of the former Ontario Hydro.

The purpose of the nonprofit IMO was to manage the pool and transmission system; the purpose of the ESA was to conduct electrical safety inspections; and the purpose of OEFC was to service and retire the former Ontario Hydro's provincially guaranteed debt and manage certain other legacy liabilities, most related to investments in nuclear power. Ontario Hydro's debt had increased from $12 billion in 1980 to $38 billion in 1999. As in the United Kingdom and California, the issue of how to address the financing of stranded costs (mostly related to nuclear power) was a major concern in Ontario's electricity reform. In Ontario, a portion of the costs are to be recovered through transition surcharges[29] [***38***, ***39***].

Rather than privatizing Ontario Power Generation outright, the Ontario government chose to introduce market principles by requiring that the new company "decontrol" generation assets. This was achieved to a small degree when Ontario Power Generation leased its Bruce nuclear power units to Bruce Power Partnership, which was 95 percent owned by British Energy. Ontario Power Generation was also ordered to shed 4,000 megawatts of assets over 3 years and to reduce its share of the province's electricity market to 35 percent by 2012. Although the provincial government had intended to privatize Hydro One as a part of the overall reform scheme, in January 2003 the provincial premier announced that it would retain full ownership of the entity [***40***]. It had intended that the proceeds from the sale of Hydro One were to be used to retire a portion of the debt (stranded costs) of the former Ontario Hydro.

In contrast to generation, Hydro One, the province's transmission operations, has continued to be regulated, although Ontario's intent was to eventually adopt a performance-based regulation, similar to the form of regulation employed in the United Kingdom. The Ontario Energy Board Act (a companion piece of legislation to the Energy Competition Act) instituted the Ontario Energy Board (OEB), which is an independent quasi-judicial entity. The OEB licenses all market participants in the electricity sector and oversees transmission and distribution rates. The board is also charged with assuring that nondiscriminatory open access is implemented in transmission.

Ontario also intended to introduce retail competition. The Competition Act envisioned full retail competition being implemented in 2000 for all classes of customers—industrial, commercial, and residential.[30] Power marketers were allowed to begin contacting potential customers in March 2000 and to enter into contracts the following November.

In May 2002, Ontario began operation of the electricity pool. The pool was similar to the California pool in that both electricity suppliers and consumers were to bid into the market, with no forward market as an alternative. The pool's pricing mechanism was set up much like the UK pool. The price offered by the last unit to clear the market (the system marginal price) became the market price that was paid to all generators.

Ontario did not, however, allow for completely competitive market-based prices. Rather, electricity consumers were allowed either to choose to purchase power at a fixed price or to choose one based on the wholesale pool price. During the summer of 2002, exceptionally hot weather sent electricity prices soaring in the pool as they attained their market-clearing levels. Although the price spikes did not come close to those experienced in the California, monthly bills showed a 20-percent increase above government forecasts [***41***]. As a result of public concern, in November 2002, Ontario's government ordered a 4.3 cents (Canadian) per kilowatthour cap on wholesale prices and rebates to consumers for previous price increases.

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[30]The Ontario Energy Board Act allowed for continued rate protection for certain classes of customers such as some rural users.

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17. M.J. Dodognet, J.M. Glachant, and, M.A. Plagnet, *Mergers and Acquisitions in the European Electricity Sector: Cases and Patterns* (Paris, France: Centre d’ Économie Industrielle Ecole Nationale Superérieure des Mines de Paris, August 2002), pp. 7 and 117.

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19. International Energy Agency, *Electricity Information 2002* (Paris, France, 2002), p. 1.69. The annual percent change is for electricity export data from OECD European nations to OECD European nations.

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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. Future actions to limit carbon dioxide emissions and global efforts to reduce the potential impacts of climate change, as well as localized policies and regulations designed to limit energy-related emissions of airborne pollutants other than carbon dioxide, are likely to affect the level, composition, and growth of global energy use.

In recent years there has been ongoing study and debate about the possible contribution of energy-related emissions of carbon dioxide and other greenhouse gases to global climate change, defined by the Intergovernmental Panel on Climate Change (IPCC) as "a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer) . . . [which] may be due to natural internal processes or external forcing, or to persistent anthropogenic changes in the composition of the atmosphere or in land use" [***1***]. Carbon dioxide, one of the most prevalent greenhouse gases in the atmosphere, has two major anthropogenic (human-caused) sources: combustion of fossil fuels and changes in land use. Net releases of carbon dioxide from these two sources are believed to be contributing to the rapid rise in atmospheric concentrations of carbon dioxide since pre-industrial times. Because estimates indicate that approximately 80 percent of all anthropogenic carbon dioxide emissions come from fossil fuel combustion, world energy use has emerged at the center of the climate change debate [***2***].

At the same time, concern about the local environmental and air quality impacts of mobile and stationary energy consumption have resulted in increasingly stringent regulation of air pollutants such as sulfur oxides, nitrogen oxides,[31] 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 2003* (*IEO2003*) 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 *IEO2003* 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. Factors such as population growth, rising personal incomes, rising standards of living, and further industrialization are expected to have a much greater influence on levels of energy consumption in developing countries than in industrialized nations. Energy-related 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.

Carbon intensity—the amount of carbon dioxide emitted per dollar of gross domestic product (GDP)—is projected to improve (decrease) throughout the world over the next two decades (Table 28). In particular, steep rates of improvement are expected among the transitional economies of Eastern Europe and the former Soviet Union (EE/FSU). 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 and increasingly use less carbon-intensive natural gas for electricity generation and other end uses in place of more carbon-intensive oil and coal. Eastern European nations have been in economic recovery longer than has the FSU, and natural gas is expected to continue to displace coal use in the region, resulting in an average 2.8-percent annual improvement (decrease) in carbon intensity for Eastern Europe as a whole.

[31] 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 that are 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 a powerful greenhouse gas.

Table 28. Carbon Intensities for Selected Countries and Regions, 2000-2025
(Metric Tons Carbon Equivalent per Thousand 1997 Dollars of GDP)

Country or Region	2001	2005	2010	2020	2025	Annual Percent Change, 2000-2025
United States	166	154	144	124	116	-1.5
Canada	209	203	190	157	146	-1.5
Mexico	213	212	193	169	161	-1.1
United Kingdom	104	95	88	77	72	-1.5
France	68	61	55	49	48	-1.4
Germany	98	90	83	70	67	-1.5
Australia/New Zealand	199	189	180	155	148	-1.2
Former Soviet Union	1,000	1,012	862	691	621	-2.0
Eastern Europe	518	430	380	291	261	-2.8
China	693	555	506	400	363	-2.7
India	480	425	386	313	285	-2.1
South Korea	217	185	169	147	137	-1.9
Turkey	270	279	270	234	220	-0.9
Brazil	109	111	110	103	97	-0.5

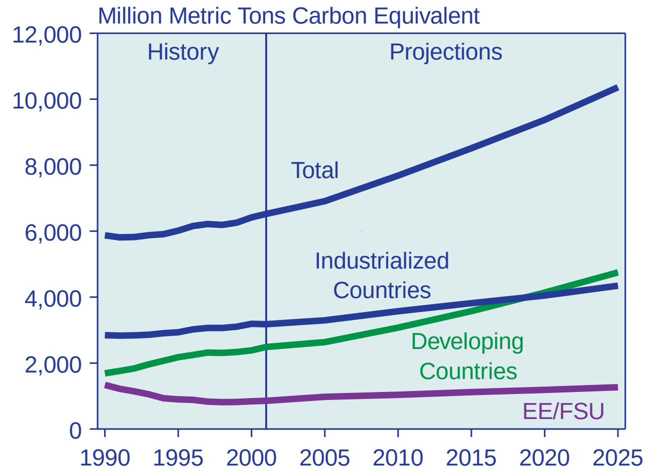
Sources: **2001:** Derived from Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **2005-2025:** EIA, System for the Analysis of Global Energy Markets (2003).

Fairly rapid improvement in carbon intensity is also projected for the large developing countries China and India, primarily as a result of rapid economic growth rather than a switch to less carbon-intensive fuels. Both China and India are projected to remain heavily dependent on fossil fuels, particularly coal, in the *IEO2003* reference case, but their combined annual GDP growth is projected to average 5.9 percent, compared with an expected 3.4-percent annual rate of increase in fossil fuel use from 2001 to 2025.

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. By 2025, developing countries are projected to account for the largest share of world carbon dioxide emissions, at 46 percent, followed by the industrialized world at 42 percent and the EE/FSU at 12 percent. The *IEO2003* projections indicate that carbon dioxide emissions from developing countries could surpass those from industrialized countries by 2020 (Figure 84).

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 85). Over the forecast period, oil is projected to remain the primary source of carbon dioxide emissions in industrialized countries because of its continued importance in the transportation sector, where there are currently few economical alternatives. Natural gas use and associated emissions are projected to increase substantially, particularly for electricity generation. By 2025, the share of natural-gas-related emissions, at 26 percent, is expected to be almost equal to that of coal.

Figure 84. 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 (2003).

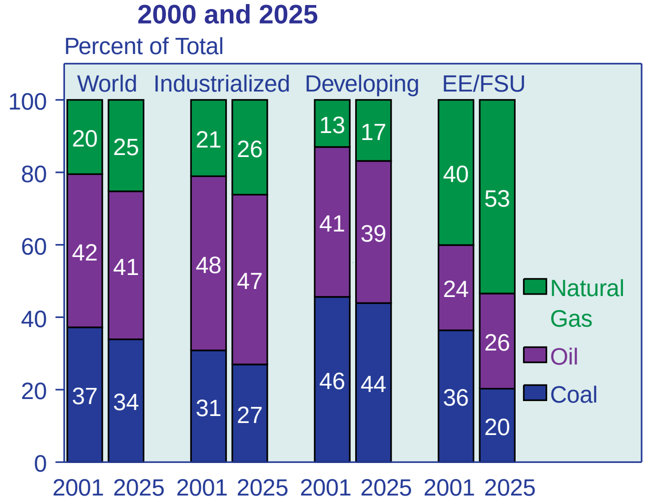
The United States is currently the largest energy consumer in the industrialized world, accounting for the majority of its energy-related carbon dioxide emissions. Natural gas and coal use for electricity generation in the United States are projected to increase over the forecast period, whereas generation from nuclear energy is expected to decline after 2010. Absent mandatory carbon reduction policies, no new nuclear plants are expected to be constructed in the United States by 2025, given the more favorable economics of competing technologies.

As a result, U.S. electricity generation is projected to become more carbon intensive over the forecast period.

With the exception of Australia, most other industrialized countries rely much less heavily on coal to meet domestic energy needs than does the United States. In Western Europe, coal consumption is projected to continue to decline over the forecast period as natural gas consumption, particularly for electricity generation, increases. The projected decline in Western Europe's carbon intensity, brought on by the continued shift in the overall energy supply toward more natural gas, is lessened somewhat by the projected decline in nuclear power generation after 2010. Germany and Sweden have committed to shutting down their nuclear power industries, and other European countries are considering similar proposals. Electricity generation from other non-emitting energy sources, such as hydroelectricity and wind power, is not expected to increase sufficiently to offset the drop in nuclear energy production in the region.

In the transitional economies of the EE/FSU region, 40 percent of energy-related carbon dioxide emissions come 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. With further development of the vast natural gas reserves in Russia and the Caspian Sea region, natural gas is expected to continue to displace coal. Oil consumption is also projected to increase in the FSU, particularly for transportation and power generation, as

Figure 85. Shares of World Carbon Dioxide Emissions by Region and Fuel Type, 2000 and 2025



Sources: **2000:** 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 (2003).

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, reaching 53 percent and 26 percent, respectively, by 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 increase significantly 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 intensity is expected to decline in Eastern Europe more than in any other region over the forecast period. Nevertheless, because the decline in carbon intensity is not expected to keep pace with growth in total energy consumption, annual carbon dioxide emissions in the region are expected to increase by nearly 35 percent between 2001 and 2025.

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. Because data on biomass use in developing nations are often sparse or inadequate, *IEO2003* does not include the combustion of biomass fuels in its coverage of current or projected energy consumption. For the United States, combustion of biomass is counted in energy consumption; however, because carbon dioxide emissions from biomass are considered to be part of the natural carbon cycle, they are not included in projections of anthropogenic carbon dioxide 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.

The largest increases in energy consumption and carbon emissions are projected for China, given the expectations for continued economic expansion and population growth. Coal reserves are abundant in China, and access to other energy fuels is limited in many parts of the country. In Central and South America, carbon dioxide emissions are expected to double between 2001 and 2025 as a result of increasing energy demand and shifts in the mix of energy fuels consumed. Many countries in

Central and South America, most notably Brazil, have relied heavily on hydropower to provide the majority of their electricity in the past; but by 2025 natural gas is expected to be a larger part of the region's energy mix.

Future levels of energy-related carbon dioxide emissions in many countries are likely to differ significantly from *IEO2003* 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 *IEO2003* 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 world community's effort to address global 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" [***3***]. That objective was reinforced during the second Earth Summit held in Johannesburg, South Africa, during the summer of 2002, where the world community reaffirmed its commitment to the principles of the Framework Convention (see box on page 161). The most ambitious proposal coming out of the annual conferences held to implement the UNFCCC has been 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 to reduce their overall greenhouse gas emissions by at least 5 percent below 1990 levels over the 2008 to 2012 period. Quantified emissions targets are differentiated by country.[32]

In addition to any domestic emission reduction measures that Annex I parties may choose to implement in order to meet their emission targets, the Kyoto Protocol allows the use of three "flexibility mechanisms" (sometimes called "Kyoto mechanisms" or "market-based mechanisms"):

- *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 equivalent more than needed to meet its target level can sell the "surplus" emission reductions to other Annex I countries.
- The *clean development mechanism* (CDM) allows Annex I countries, through governments or other legal entities, to invest in emission reduction or sink enhancement projects in non-Annex I countries, gain credit for those "foreign" emissions reductions, and then apply the credits toward their own national emission reduction commitments.
- *Joint implementation* (JI) is similar to the clean development mechanism, but the investment in emission reduction projects must occur within the 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 relatively greater reductions of other greenhouse gas emissions and smaller reductions of carbon dioxide 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 [***4***].

Changes in emission levels resulting from human-induced actions that release carbon dioxide and other greenhouse gases or remove them from the atmosphere via "sinks" (trees, plants, and soils) are also allowed as reductions under the Protocol, subject to certain restrictions. The extent to which each Annex I party makes use of sinks and the mechanisms for counting the offsets will influence the amounts needed in domestic emission reductions needed to comply with the Protocol.

Details of the operation of the Kyoto Protocol have been the subject of several UNFCCC meetings since COP-3.

[32]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.

The finalized agreements reached by the end of COP-7, held in Marrakech, Morocco, in fall 2001 stipulate that forests, cropland, and grazing land management can be used to increase the amount of carbon sequestered in biologic sinks during the first commitment period (2008-2012), subject to some country-specific upper bounds; afforestation and reforestation projects can be eligible for the CDM; and no quantitative limits can be placed on JI, CDM, and emissions credit trading as means of meeting the Kyoto commitments. The Bonn

Johannesburg, South Africa, 2002 World Summit on Sustainable Development

From August 26 to September 6, 2002, the United Nations World Summit on Sustainable Development was held in Johannesburg, South Africa. Its objective was to review progress on sustainable development commitments made at earlier international meetings—such as the UN Conference on Environment and Development (Rio de Janeiro, 1992)—and to develop an action plan for protecting the environment and eradicating poverty in coming decades, which is the goal of sustainable development.[a]

The summit produced few hard targets or timetables. In particular, no further commitments were made to address the issue of climate change aside from a general reaffirmation of the principles of the UNFCCC and a statement by countries that have ratified the Kyoto Protocol strongly urging other states to follow suit. Several of the decisions that were adopted,[b] as summarized below, will have implications for future energy use in developed and developing countries.

- *Renewable Energy*: Diversify energy supply and substantially increase the global share of renewable energy sources.
- *Access to Energy*: Improve access to reliable, affordable, economically viable, socially acceptable and environmentally sound energy services and resources, sufficient to achieve the Millennium Development Goals, including the goal of halving the proportion of people in poverty by 2015.
- *Energy Markets:* Remove market distortions, including restructuring of energy taxes and phasing out harmful subsidies.

Specific funding initiatives from the summit that target the energy sector are described in the table below.

Energy-Related Funding Announcements From the Johannesburg Summit

Sponsor	Funding Initiative
Canada	By 2003, eliminate all tariffs and quotas on products from least developed countries. Double development assistance by 2010.
European Union	$700 million partnership initiative on energy. $3 billion for Global Environment Facility. Raise development assistance by 22 billion euros until 2006 and 9 billion euros annually from 2006 onward.
Germany	500 million euros over next 5 years to promote cooperation on renewable energy.
Japan	Environment-related training of 5,000 overseas people during a 5-year period.
Norway	$50 million for implementing Johannesburg commitments.
United Kingdom	Double assistance to Africa to £1 billion a year; 50-percent increase in assistance to all countries.
United States	Up to $43 million for energy partnerships and projects in 2003.
E7 Electricity Companies[a]	Agreements with the UN on technical cooperation for sustainable energy projects in developing countries.
UN Environment Programme	Launched Global Network on Energy for Sustainable Development to promote research, transfer and deployment of green and cleaner technologies to the developing world.
UN Environment Programme, UN Department of Economic and Social Affairs (DESA), U.S. Environmental Protection Agency	Partnership with DESA and U.S. EPA on cleaner fuels and vehicles, with partners from private sector, nongovernment organizations, developed and developing countries.

[a]American Electric Power (U.S.), Electricité de France (France), Enel (Italy), HydroQuébec (Canada), Ontario Power Generation (Canada), Kansai Electric Power (Japan), RWE (Germany), Scottish Power (UK), and Tokyo Electric Power (Japan).

Note: Funding initiatives targeting such other issues as water, poverty reduction, health, and natural resources are not included in this table.

Source: United Nations Department of Economic and Social Affairs, Division for Sustainable Development, "Johannesburg Summit 2002: Key Outcomes of the Summit" (September 2002), web site www.johannesburgsummit.org/html/documents/summit_docs/2009_keyoutcomes_commitments.pdf.

[a]United Nations Department of Economic and Social Affairs (DESA), Division for Sustainable Development, "World Summit on Sustainable Development: Plan of Implementation," web site www.johannesburgsummit.org/html/documents/summit_docs/2309_planfinal.htm.

[b]United Nations Department of Economic and Social Affairs (DESA), Division for Sustainable Development, "Johannesburg Summit 2002: Key Outcomes of the Summit" (September 2002), web site www.johannesburgsummit.org/html/documents/summit_docs/2009_keyoutcomes_commitments.pdf.

agreement also calls for 2 percent of the revenues raised from certified emission reductions issued for any CDM project to go toward a fund for climate change adaptation projects in developing countries.

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, accounting rules for carbon sink projects, and whether the consequences for noncompliance in meeting national emission reduction targets should be legally binding. A new debate over next steps in the development of a climate change regime was introduced during the 2002 COP-8 meeting in New Delhi, India, including discussion of binding commitments for developing countries (see box below).

The Kyoto Protocol enters 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. As of February 2003, 104 countries had ratified the Protocol, including Canada, China, India, Japan, Mexico, New Zealand, South Korea, and the European Union. A total of 30 Annex I countries, representing 43.9 percent of total 1990 carbon dioxide emissions, have signed on to the treaty (Figure 86). 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 of the Protocol would bring the total to 61.3 percent and enable the Kyoto Protocol to enter into force—regardless of the American and Australian decision not to participate. The Russian President has announced Russia's intention to ratify the treaty, but the timing of such action is still uncertain [***5***].

Although the United States has announced that it will not participate in the Kyoto Protocol, the government has introduced a series of alternative measures to reduce greenhouse gas emissions. In 2001, President Bush committed the U.S. government to the pursuit of a broad

COP-8 Climate Change Negotiations in New Delhi, India

The Eighth Session of the Conference of Parties (COP-8) to the UNFCCC was held in New Delhi, India, from October 23 to November 1, 2002, to continue discussion on the Kyoto Protocol and implementation of the UNFCCC. With the Kyoto Protocol not yet in force, agenda items focused mostly on technical issues that had been left out of the Kyoto agreements of COP-6.5 and COP-7. Notable decisions include:

Kyoto Protocol:

- Rules for small-scale CDM projects and accreditation procedures for operational entities.
- Guidelines for tracking emission transfers in a uniform format to allow linkage of JI, CDM, and emissions trading activities in national emission registries.
- Procedures for expert review of registries to assess compliance with requirements on "commitment period reserves" to avoid overselling of allowances.

UNFCCC:

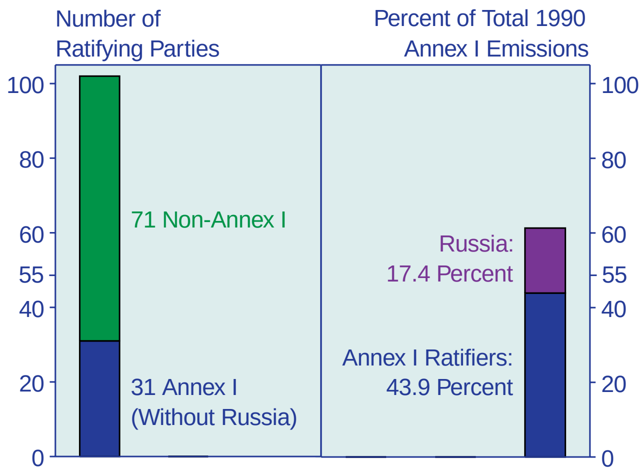
- Guidance for two of the three new developing country funds (the least developed countries fund and the special climate change fund) established at COP-7.
- Invitation to the IPCC and the Montreal Protocol's Technology and Economic Assessment Panel to undertake a special report on hydrofluorocarbons and perfluorocarbons.

Political discussions also focused on potential next steps in the development of a climate change regime, including a debate on the proposed Delhi Ministerial Declaration designed to shape the direction of future negotiations. While the Indian government focused negotiations around developing country concerns, such as vulnerability and adaptation to the effects of climate change, developed countries, led by the EU, focused on the need to develop longer term commitments beyond the first Kyoto commitment period.

In particular, the EU proposed the development of a broader, more inclusive, and balanced process for commitments after 2012, opening the door for inclusion of developing countries in future commitments. This suggestion was met with strong resistance by developing countries. The final Delhi Ministerial Declaration on Climate Change thus excludes references to forward-looking strategies and instead reaffirms and highlights the need for sustainable economic and social development in the developing countries and increased support for adaptation measures.

Sources: Pew Center on Global Climate Change, "Climate Talks in Delhi - COP8: Summary (November 1, 2002), web site www.pewclimate.org/cop8/summary.cfm; Baker & McKenzie, "Climate Change Negotiations: COP8 Outcomes" (December 2002), web site www.ieta.org/Documents/New_Documents/COP8_Outcomes_and_Implications_v3.PDF.

Figure 86. Progress Toward Ratification of the Kyoto Protocol, as of January 1, 2003



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).

range of strategies to address the issues of global climate change, launching three initiatives: the Climate Change Research Initiative to accelerate science-based climate change policy development; the National Climate Change Technology Initiative to advance energy and sequestration technology development; and increased international cooperation to engage and support other nations on climate change research and clean technologies [***6***].

On February 14, 2002, President Bush announced the Administration's Global Climate Change Initiative, which calls on the United States to reduce greenhouse gas intensity (total greenhouse gas emissions per unit of gross domestic product) by 18 percent between 2002 and 2012, primarily through voluntary measures (**see box below**). Under the Global Climate Change Initiative, the President directed the Secretary of Energy to propose improvements in the Department of Energy's Voluntary Reporting of Greenhouse Gases Program to enhance the accuracy, reliability, and verifiability of emission reduction measurements reported to the program. Reforms to the program are to ensure that businesses and individuals registering reductions will not be penalized under a future climate policy, and to give transferable credits to companies that can show real emission reductions [***7***, ***8***].

On February 12, 2003, the U.S. Department of Energy, on behalf of President Bush, launched the President's "Climate VISION" (Voluntary Innovative Sector Initiatives: Opportunities Now). Climate VISION is a voluntary, public-private partnership to pursue cost-effective initiatives to reduce the projected growth in U.S. greenhouse gas emissions. The program, to be administered through the Department of Energy, is intended to help meet the President's goal of reducing U.S. greenhouse gas intensity by 18 percent between 2002 and 2012. It involves Federal agencies, including the Department of Energy, Environmental Protection Agency, Department of Agriculture, and Department of Transportation, working with industrial partners to reduce greenhouse gas emissions voluntarily over the next decade. Industry groups making commitments include the Alliance of Automobile Manufacturers, Aluminum Association, American Chemistry Council, American Forest and Paper Association, American Iron and Steel Institute, American Petroleum Institute, American Public Power Association, Association of American Railroads, Business Roundtable, Edison Electric Institute, Electric Power Supply Association, Magnesium Coalition and the International Magnesium Association, National Mining Association, National Rural Electric Cooperative Association, Nuclear Energy Institute, Portland

U.S. Greenhouse Gas Intensity Target

In February 2002, President Bush introduced the Climate Change Initiative to address the issue of global warming. As a cornerstone of the initiative, the President set a target of reducing the greenhouse gas intensity of the U.S. economy by 18 percent over the next 10 years.[a] Greenhouse gas intensity measures the ratio of greenhouse gas emissions (carbon dioxide equivalent) to economic output (dollars of gross domestic product). The intensity-based greenhouse gas reduction target can be met without reducing or stabilizing annual U.S. emissions of carbon dioxide, so long as annual economic growth is greater than the increase in emissions.

The greenhouse gas intensity of the U.S. economy has declined steadily in past decades, and continued declines are expected in the future. The Bush Administration's proposal assumes that, with business-as-usual emissions rates, greenhouse gas intensity will decline by 14 percent between 2002 and 2012. Measures included in the Climate Change Initiative are expected to reduce the intensity by an additional 4 percent, by producing an absolute reduction in emissions of 100 million metric tons carbon equivalent in 2012 and more than 500 million metric tons cumulatively over the 2002-2012 period.

[a]"President Announces Clear Skies & Global Climate Change Initiatives," web site www.whitehouse.gov/news/releases/2002/02/20020214-5.html (February 14, 2002).

Cement Association, and Semiconductor Industry Association.

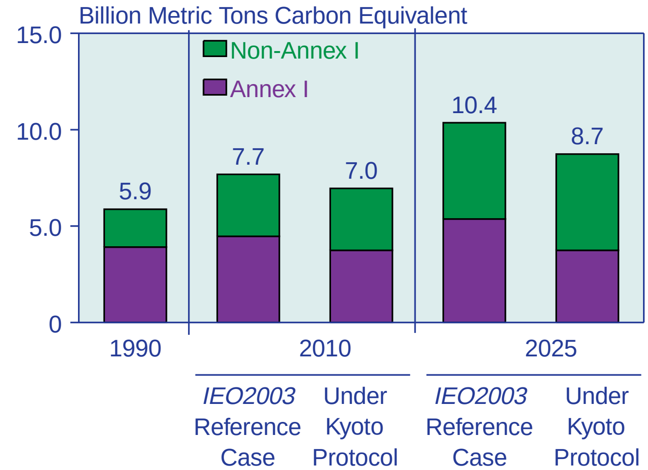
Many other Annex I countries have initiated measures to reduce greenhouse gas emissions and meet projected emissions targets. Policies target all areas of energy use in industry, energy production, transportation, and buildings. Table 29 highlights some of the measures taken by individual countries.

The *IEO2003* 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 by 14 percent in 2010 (Figure 87). Taking the prescribed Kyoto emission reduction targets on the basis of energy-related carbon dioxide emissions alone, the industrialized Annex I countries would face an emission limit of 2,575 million metric tons carbon dioxide equivalent in 2010, or 25 percent less than their projected baseline emissions. On the other hand, energy-related carbon dioxide emissions from the group of transitional Annex I countries have been decreasing since 1990 as a result of economic and political crises in the EE/FSU. The combined Kyoto Protocol reduction target for the transitional Annex I countries is 10 percent below their projected 2010 baseline emissions. Of the industrialized Annex I countries, Finland, Germany, Luxembourg, Sweden, and the United Kingdom had reduced energy-related carbon dioxide emissions below their 1990 levels in 2000.

Greenhouse Gas Emissions Trading

At COP-7 in Marrakech, it was established that international emissions trading under the Kyoto Protocol could start as of 2008. In advance of any international emissions 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

Figure 87. Carbon Dioxide Emissions in Annex I and Non-Annex I Nations Under the Kyoto Protocol, 2010 and 2025



Sources: **1990:** 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 (2003).

Table 29. 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 (California): Carbon dioxide emission reductions for cars and light-duty vehicles (2002)	Australia: Campaign for energy efficiency awareness	Denmark, Finland, Italy, Netherlands, New Zealand, Norway, and Sweden: Carbon tax	Australia: Industry-owned green electricity market	United Kingdom: Emissions trading system (2002)
Norway: Energy labels for household appliances	France: Mass media climate change campaign	Luxembourg: Grants for purchase of efficient vehicles (2001)	Japan: Industry (Keidanren) action plan to reduce emissions	Austria: Green certificate trading (2000)
Finland: Replacing coal-fired power generation	United Kingdom: The Carbon Trust, a nonprofit organization to promote energy efficiency in nondomestic sectors	United Kingdom: Road taxation linked to carbon dioxide emissions	European Union: Agreement with European/Korean/Japanese car manufacturers to increase vehicle efficiency of new models (2000)	Denmark: Carbon dioxide emission trading
Australia: Fuel consumption labels on cars (2001)	Belgium: Planning to increase rail transport by 15 percent	Canada: Subsidies for commercial and institutional building retrofits	Germany: Industrial and energy sector promotion of combined heat and power generation	Belgium: Combined heat and power certificate market
United Kingdom: Renewables obligation on electricity supply		Netherlands: "Eco-tax" exemptions for green electricity use		

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.

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 carbon dioxide equivalent. 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 is not new, having been used in the United States since the 1990s to achieve reductions in stationary-source emissions of sulfur dioxide and in the fisheries industry. In the late 1980s New Zealand introduced an individual transferable quota (ITQ) 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 [***9***].

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 non-capped industries and entities that would trade voluntarily created, permanent emission reductions 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 level that would otherwise occur under business as usual, 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.

In October 2001, the European Commission of the EU released a final proposal for establishing its own internal greenhouse gas emissions trading system [***10***]. The first trial phase of the scheme would run from 2005 through 2007, regulating carbon dioxide emissions from all heat and electricity generators over 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 would require operators of such installations to hold permits as a condition for emitting greenhouse gases. The second phase of the scheme would be concurrent with the first compliance period under the Kyoto Protocol (2008-2012), should it come into force, and each subsequent phase would last for 5 years.

The EU member states would determine the quantity of allowances to be issued in each phase. Noncompliance sanctions would be applied to any installation that did not have enough allowances to cover actual emissions each year. The allowances, which would be tradable across the entire EU, could be banked from year to year within each phase, and across phases if individual member states decided to do so.

In fall 2002, the European Parliament and the Council of Ministers separately approved the Commission’s proposal, adding a number of amendments to the scheme [***11***]. For example, the Council of Ministers voted for mandatory participation by Member States from 2005, but inserted the provision that Member States should have limited rights to exempt individual sectors, activities, or installations until 2008 if comparable emission reductions were already being undertaken. Moreover, the Council would allow Member States to include additional sectors and other greenhouse gases only after 2008, contradicting an earlier Parliamentary amendment to do so by 2005. On the issue of permit allocation, the Parliament introduced a “hybrid scheme” whereby—for the whole of the 2005-2012 period—15 percent of the permits should be auctioned and the rest allocated for free. However, the Council of Ministers would limit auctioning to 10 percent, and only during the second phase. The directive is pending final approval by the European Parliament and could be delayed until 2004 if the Council and Parliament have difficulties reaching an agreement.

The EU proposal was 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 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 project 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, Sweden, and the United Kingdom, are considering development of their own national trading programs. Non-EU countries, including Japan, Norway, 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 [12]. A cap of 22 million metric tons of carbon dioxide was set for 2001, with reductions of 1 million metric tons per year during the 3-year life of the program. The trading system became operational in April 2001 and will run through 2003. Free allowances were allocated to eight firms, based on their fuel consumption and actual emissions during the 1994-1998 period, excluding emissions from puchased power. 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 equivalent reductions computed against their targets. Also in contrast to the EU proposal, the UK scheme is based on voluntary targets, includes all six Protocol gases, and excludes combined heat and power generators, except for emissions from electricity usage that is generated and used on-site.

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, more than 280 carbon transactions have taken place, amounting to some 335 million metric tons of carbon dioxide equivalent emission reductions [13]. About half of the trades were negotiated in 2002. Major market drivers include the UK emissions trading scheme, the World Bank's Prototype Carbon Fund, and the Dutch government's ERUPT and CERUPT programs to purchase JI and CDM credits. As illustrated in Table 30, emission reductions purchased by the Prototype Carbon Fund range between \$3 and \$4 per metric ton carbon dioxide equivalent, and credits purchased by the Dutch government range between \$4 and \$5 per metric ton [14]. As of fall 2002, credits traded in the British system were valued at about \$18 per metric ton.

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 UK emissions trading system, and the proposed directive for a European-wide trading scheme. In 1996, 100 percent of carbon emissions trades took place in the United States; in 2002, more than one-half of the 150 carbon deals negotiated in 2002 took place in Europe. Emissions trading activity in the United States could increase, however, with the expected opening of the Chicago Climate Exchange (CCX) in spring 2003. CCX is a voluntary cap and trade program. Participating members will be able to buy and sell greenhouse gas credits to assist in achieving their emission reduction commitments.

Abating Other Energy-Related Emissions

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, particulate matter, and volatile organic compounds, because of their contribution to ozone and smog formation, acid rain, and various human health problems (see **Table 31** for a summary of the possible health and environmental effects of these pollutants). 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 in most of the countries with active nuclear power programs there is no 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

Table 30. Greenhouse Gas Credit Prices by Trading Program

Greenhouse Gas Trading System	Credit Price (2002 Dollars per Metric ton Carbon Dioxide Equivalent)
United Kingdom, Auction System	23
United Kingdom, Emissions Trading System	7-18
Dutch Government, ERUPT and CERUPT	4-5
World Bank, Prototype Carbon Fund	3-4
Denmark, Emissions Trading System	2-4
North America, Private Transactions	1-2
Other	0.5-5

Sources: A.C. Christiansen, "Overview of European Emissions Trading Programs," Point Carbon Presentation at EMA 6th Annual Fall Meeting and International Conference (Toronto, Canada, September 29-October 1, 2002); F. Lecocq and K. Capoor, "State and Trends of the Carbon Market," PowerPoint Presentation Prepared for PCF*plus* Research (October 2002); Point Carbon, "ViewPoint: The UK ETS Quieting Down," *Europe Weekly* (February 21, 2003), web site www.pointcarbon.com.

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 from primary gaseous emissions. 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 [***15***].

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 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 [***16***]. In contrast to the generally rising trend in nitrogen oxide emissions, emissions of volatile organic compounds have declined [***17***]. To continue combating ground-level ozone formation, several countries plan to tighten emissions standards for new vehicles over the coming years (Table 32). 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 33).

The regulation of mercury emissions from energy use has recently become an area of particular interest in industrialized countries. Over the past decade, many nations have begun to evaluate the potential adverse effects of mercury on human health and the environment. 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, energy-related mercury regulations have focused on municipal solid waste combustion. However, as coal-fired boilers contribute the single largest share of both energy-related and non-energy-related mercury emissions, countries that rely heavily on coal-fired power generation are beginning to consider limits on mercury emissions from power plants [***18***] (see box on page 169).

Table 31. 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.	Respiratory and heart problems, acid rain, and haze.
Mercury (Hg)	Metallic element, which 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.

Sources: U.S. Environmental Protection Agency, *Latest Findings on National Air Quality: 2001 Status and Trends*, EPA 454/K-02-001 (Washington, DC, September 2002); 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).

United States

In the United States, the main initiatives to reduce air pollution stem from the 1970 Clean Air Act—the comprehensive Federal law that regulates air emissions from stationary and mobile sources—and the subsequent Clean Air Act Amendments of 1990 (CAAA90), which designate stricter emissions goals and standards across a wider range of pollutants.

In the sections related to stationary energy use, the Clean Air Act and its amendments address all the major air quality issues, such as acid rain, ground level ozone, and visibility. The Acid Rain Program, introduced under Title IV of CAAA90, 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. The program also 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 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. emissions at 8.95 million metric tons by 2010.[33] 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 emissions allowance trading

Table 32. 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 commerical 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 33. 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).

[33]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 continuation page).[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 are working on developing a nationwide emission standard for the coal-fired electricity generation sector by the end of 2005.
- The United States is debating various multi-pollutant legislative initiatives, with mercury as one of the targeted pollutants. On December 14, 2000, the U.S. Environmental Protection Agency announced the decision that it is appropriate and necessary to regulate hazardous air pollutants (including mercury) from electric utility power plants.[e] A regulation is currently scheduled for proposal by December 15, 2003, and promulgation by December 15, 2004.
- 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 daughter directive under the 1996 Air Quality Framework Directive (96/62/EC).

(continued on page 170)

Emissions of Mercury from Anthropogenic Sources by World Region, 1995
(Metric Tons per Year)

Region	Source of Emissions					Total
	Stationary Combustion of Fossil Fuels	Nonferrous Metal Production	Pig Iron and Steel Production	Cement Production	Waste Disposal	
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]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.

and banking. 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 [***19***].

Specifications for reducing nitrogen oxide emissions under the Acid Rain Program are also scheduled according to two phases. As with the sulfur dioxide rules, the Phase II nitrogen oxide limits, targeting certain coal-fired utility boilers, became effective in January 2000; however, the nitrogen oxide program neither sets an emissions cap nor incorporates emissions allowance trading as a compliance option. The program requires utility boilers to meet a specified nitrogen oxide emissions rate, depending on boiler capacity, providing flexibility for utilities by focusing on the emission rate to be achieved.

The U.S. Environmental Protection Agency (EPA) has also taken two actions to address the effects of interstate transport of nitrogen oxide emissions on downwind ozone nonattainment areas. In 1998, the EPA finalized the "nitrogen oxides SIP call" rules, which now require 19 States and the District of Columbia to revise their State Implementation Plans (SIPs) to control summertime nitrogen oxide emissions. In a separate action, aimed at the same interstate nitrogen oxides transport problem, the EPA in December 1999 found that emissions from large electric generating units and large industrial boilers and turbines in 12 States and the District of Columbia are significantly contributing to downwind States' ozone nonattainment problems. The rule requires the sources to control summertime nitrogen oxide emissions under the Federal Nitrogen Oxides Budget Trading Program, beginning May 1, 2003[34] [***20***].

Additional requirements for electric power plant operators to reduce sulfur dioxide and nitrogen oxide emissions beyond the levels called for in current regulations are being considered at Federal levels (see box on page 171). It is envisioned that the new regulations will eliminate several of the individual programs that apply to the power generation sector and replace them with a less burdensome administrative system.

Controlling Emissions of Mercury from Energy Use (Continued)

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. Recommendations included the creation of an international legally binding treaty to reduce or eliminate mercury use and emissions.[f]

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/m3	
China	Incineration (average)	0.2 mg/m3	
Croatia	Incineration with gas flow of 10 g/h or more	1 mg/m3	
European Union	Incineration at 11% Oxygen (average over period of minimum 30 minutes and maximum 8 hours)	0.05 mg/m3	
Germany	Incineration at 11% Oxygen (daily maximum average)	0.03 mg/m3	
	Incineration at 11% Oxygen (half hour average)	0.05 mg/m3	
Norway	Incineration, facilities permitted after 1994 (average)	0.03 mg/m3	
South Korea	Incineration (average)	5 mg/m3	0.1 mg/m3 (January 1, 2005)
United States	Incineration at 7% oxygen (daily maximum)	0.08 mg/m3	

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.

[f]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.

[34]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 NO_X emissions cap-and-trade program.

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 current Federal legislative initiatives 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 either override or streamline the 1990 Clean Air Act's New Source Review requirements for modernization at power plants built before the Clean Air Act and exempt from its regulations.

Three major legislative initiatives have been 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 Senators Jeffords and Lieberman 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 Maximum Achievable Control Technology (MACT) requirement to reduce mercury emissions. The current Clean Air Act requires the U.S. Environmental Protection Agency 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 Initiative

(continued on page 172)

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 Tons)
		Current Emission Levels from Fossil-Fueled Electricity Generation (2000)[a]			
		5.7	11.8	48	2,044 in 1990; 2,566 in 2000
		Proposed Reduction Goals and Time Table			
Clear Skies Initiative	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	26 tons in 2010; 15 tons in 2018	Voluntary
Clean Power Act of 2003	James Jeffords (I-VT)	1.5 million tons by 2009	2.25 million tons by 2009	5 tons by 2008; 2.48 g/GWhr MACT in 2008	2,050 million metric tons by 2009
Clean Air Planning Act of 2003	Tom Carper (D-DE)	1.87 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[b] 1990 level by 2016

[a]Sources: Electric Power Annual 2001. Energy Information Administration. U.S. Department of Energy. March 2003 for data on nitrogen oxides, sulfur dioxides and carbon dioxide. Data on mercury obtained from "Air Quality: Multi-Pollutant Legislation" Congressional Research Service. CRS Report Number RL31326. Updated October 22, 2002.

[b]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.

Sources: U.S. Senator Tom Carper, "Carper-Chafee-Breaux-Baucus Offer '4 Pollutant Bill': Bipartisan Senators Introduce Clean Air Legislation," Press Release (Washington, DC, October 18, 2002), web site http://carper.senate.gov/press/02/10/101802.html; and L. Parker and J. Blodgett, *Air Quality: Multi-Pollutant Legislation* (Washington, DC: Congressional Research Service, Library of Congress, October 22, 2002), web site www.ncseonline.org/NLE/CRSreports/Nov02/RL31326.pdf.

In an effort to address the EPA requirement to promulgate mercury regulations by 2004, the proposed regulations will also for the first time target emissions of mercury from stationary combustion. The CAAA90 required the EPA to study and prepare a report to Congress on the hazards to human health that can reasonably be expected to occur as a result of emissions of hazardous air pollutants (HAPs) from fossil-fuel-fired electric power plants. In its December 2000 report to Congress, the EPA found that HAP control is appropriate for coal-fired and oil-fired utility boilers, with a particular focus on mercury emissions. A regulation is currently scheduled for proposal by December 15, 2003, and promulgation by December 15, 2004. In order to ensure that optimal alternatives will be available to reduce mercury emissions, an interagency effort is underway to develop "maximum achievable control technology" (MACT) options for inclusion in future regulation.

Because particulate matter consists of many different particles, and volatile organic compounds contribute to both particulate matter and ozone, the EPA sets general national ambient air quality standards for ozone and particulate matter that apply to metropolitan areas, rather than specifying emissions limits for individual polluters. It is then up to States and urban jurisdictions to regulate local emitters. In 1997 the EPA issued new ambient air quality standards for particulate matter and ozone. The ozone standard was tightened from 0.12 parts per million measured over 1 hour to 0.08 parts per million measured over 8 hours. In addition, the EPA added two new standards for particles with diameters of 2.5 micrometers or less, set at 15 micrograms per cubic meter and 65 micrograms per cubic meter, respectively, for the annual and 24-hour standards. These were added to the existing requirements for particles with diameters of 10 micrometers or less, which were set at 50 micrograms per cubic meter and 150 micrograms per cubic meter, respectively, for the annual and 24-hour standards.

Beginning in 2002, based on 3 years of monitored data, the EPA will designate areas as nonattainment that do not meet the new particulate matter standards. Moreover, based on new scientific evidence, the EPA has proposed revisions to both standards and is developing a two-phase, integrated implementation strategy for ozone, particulate matter, and regional haze programs. Currently, it is expected that nonattainment areas will be designated sometime between 2003 and 2005, and SIPs will have to be submitted to the EPA 2 to 3 years beyond that date. As a result, further emission reductions probably will not be required until sometime between 2007 and 2010.

CAAA90 also designates more stringent emissions standards for motor vehicles. The "Tier 1" standards cover emissions of several pollutants from light-duty vehicles, beginning with model year 1994. Tighter "Tier 2" standards, which are about 90 percent cleaner than Tier 1, will be phased in starting in 2004, marking the first time that cars and light-duty trucks will be subject to the same national pollution control system. The current emissions standards for heavy-duty vehicles, which have been in place since 1998, will be further tightened in two stages:

Multi-Pollutant Legislation in the United States (Continued)

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. It has been promoted as a bipartisan bill that presents a compromise between the Clear Skies Initiative and the Clean Power Act. It would establish aggressive caps on emissions on 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 2005 levels by 2008 and to 2001 levels by 2012, whereas the Clean power Act would reduce carbon dioxide emissions to 1999 levels by 2008. 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 who produce 10,000 metric tons carbon equivalent 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.

a new combined nitrogen oxide and hydrocarbon emission standard will take effect in 2004, and further emission reductions will be phased in starting in 2007 [***21***, ***22***]. Monetary penalties will be imposed on manufacturers of heavy-duty trucks and buses that are unable to meet the tighter emissions standards.

Concurrent with the introduction of Tier 2 emissions standards, the U.S. government is requiring a reduction in the sulfur content of gasoline and diesel used for transportation [***23***, ***24***]. The lower sulfur content will enable the effective use of modern pollution-control technology required for meeting the Tier 2 standards and will significantly reduce formation of smog and particulate matter. The new gasoline sulfur standard will be phased in between 2004 and 2007, in order to ease the transition for domestic refineries. According to the new standard, refiners and importers must produce a 97-percent reduction in the sulfur content of highway diesel by June 1, 2006, although the law incorporates a phase-in period and hardship provisions for small refiners through May 2010. In addition to these rules, the EPA also expects to tighten regulations for nonroad vehicles to reduce ozone and particulate matter emissions [***25***].

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 emission limits for sulfur dioxide, nitrogen oxide, and particulate matter from new coal-, oil-, and gas-fired steam-electric power plants [***26***]. The new emission targets would lower sulfur dioxide emissions by 75 percent, to a rate of 4.24, 2.65, or 0.53 kilogram per megawatthour, depending on the energy content and sulfur concentration of the fuel used. Emissions of nitrogen oxide would be lowered by 60 percent, to a rate of 0.69 kilogram per megawatthour, and emissions of particulate matter would be lowered by 80 percent, to 0.095 kilogram per megawatthour. 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.[35] 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 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 pollutants between the two countries. Actions taken under the various sulfur dioxide and nitrogen oxide programs of the U.S. CAAA90 have supplemented Canada's domestic efforts. In addition, a December 2002 cross-border agreement between Canada and the United States set a target of cutting ozone in the U.S./Canada transboundary region by 43 percent by 2010 [***27***]. 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, model year 2004 and later vehicles will be required to meet the U.S. Tier 2 standards taking effect that same year [***28***]. In addition, the Canadian government has reached an agreement with vehicle manufacturers to equip new light-duty vehicles and trucks with the same emissions control and monitoring equipment needed to meet the U.S. Federal emissions standards for the 2001-2003 model years. In 1999, Canada approved a limit of 30 parts per million of sulfur content in gasoline, which would take effect by January 1, 2005. The average level of sulfur in Canadian gasoline is currently 350 parts per million, among the highest in the industrialized world. 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. Although industrial growth is causing increased environmental damage, transportation continues to be the largest source of emissions, contributing an estimated 70 percent of the local air pollution in Mexico City and the surrounding valley [***29***].

The Mexican government has presented several innovative proposals for fighting air pollution from transportation, including tax incentives for using cleaner fuels and

[35]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.

smog control measures. In major urban centers, private car drivers are required to have catalytic converters or refrain from driving one day a week. In addition, dozens of manufacturers are taking advantage of government subsidies to outfit gasoline-powered delivery trucks with cleaner liquefied petroleum gas. The pollution control measures put in place in the mid-1990s have already improved visibility and air quality in Mexico City.

Mexican environmental initiatives also include developing clean taxis and small buses in order to reduce urban emissions. Mexico began producing cars with emissions controls in 1991. Since then, Pemex, the national oil company, has been reducing production of leaded gasoline. The company is in the process of desulfurizing crude oil at the Tula refinery and has replaced its high-sulfur diesel with a new “Pemex diesel” that contains only 0.05 percent sulfur.

Europe

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. As with previous CLRTAP protocols, the Gothenburg Protocol specifies tight limit values for specific emissions sources based on the critical loads concept, and requires best available technologies to be used to achieve the emissions reductions. As of January 2003, only Denmark, Luxembourg, Norway, and Sweden had ratified the Gothenburg Protocol.

Parallel to CLRTAP developments, the EU agreed on the directive for National Emission Ceilings (NEC) for Certain Atmospheric Pollutants (Directive 2001 / 81 / EC) to reduce overall sulfur dioxide emissions by 63 percent and cut emissions of nitrogen oxides, volatile organic compounds, and ammonia by 40 percent by 2010 [***30***]. The agreement, which was reached at the end of 2001, covers the same four pollutants as the Gothenburg Protocol; however, the national emission targets are stricter, particularly for sulfur dioxide (Table 34). The establishment of national emission ceilings is a regulatory innovation in EU air pollution control, in that the different emissions ceilings are tailored to meet country-specific circumstances and allow member countries flexibility in implementing control measures.

While the NEC directive 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

Table 34. Emission Ceilings in the European Union National Emission Ceilings (NEC) Directive and the Convention on Long-Range Transboundary Air Pollution (CLRTAP) of the Gothenburg Protocol, 2010
(Thousand Metric Tons)

Country	Sulfur Dioxide		Nitrogen Oxides		Volatile Organic Compounds		Ammonia	
	NEC	CLRTAP	NEC	CLRTAP	NEC	CLRTAP	NEC	CLRTAP
Austria	39	39	103	107	159	159	66	66
Belgium	99	106	176	181	139	144	74	74
Denmark	55	55	127	127	85	85	69	69
Finland	110	116	170	170	130	130	31	31
France	375	400	810	860	1,050	1,100	780	780
Germany	520	550	1,051	1,081	995	995	550	550
Greece	523	546	344	344	261	261	73	73
Ireland	42	42	65	65	55	55	116	116
Italy	475	500	990	1,000	1,159	1,159	419	419
Luxembourg	4	4	11	11	9	9	7	7
Netherlands	50	50	260	266	185	191	128	128
Portugal	160	170	250	260	180	202	90	108
Spain	746	774	847	847	662	669	353	353
Sweden	67	67	148	148	241	241	57	57
United Kingdom	585	625	1,167	1,181	1,200	1,200	297	297
Total	**3,850**	**4,044**	**6,519**	**6,648**	**6,510**	**6,600**	**3,110**	**3,128**

Source: United Nations Economic Commission for Europe, Convention on Long-Range Transboundary Air Pollution, *Protocol To Abate Acidification, Eutrophication and Ground-Level Ozone, Annex II, Emission Ceilings* (Geneva, Switzerland: UNECE, 1999).

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 the 2001 directive on NECs, toward the development of a comprehensive EU acidification strategy. 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. Directive 98/70/EC designates current and future sulfur content limits for motor fuels. 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 an amendment to Directive 98/70/EC that includes the mandatory introduction of sulfur-free gasoline and diesel fuels, with sulfur levels lower than 10 milligams per kilogram, by January 1, 2005, and a complete ban on all non-sulfur-free fuels by January 1, 2009 [***31***, ***32***]. The implementation of the measure would coincide with the introduction of Euro 4 vehicles in the European market.

Australia

In Australia, measures to reduce emissions of sulfur dioxide, nitrogen oxide, volatile organic compounds, and particulate matter from energy use have focused on the transportation sector. Australia relies heavily on domestic coal for electricity generation, with 60 percent of its generating capacity being coal-fired [***33***]; however, its domestic coal has lower sulfur content than the coal produced in most other countries, and sulfur dioxide emissions from power generation are relatively low. The ambient air concentrations of sulfur dioxide in most Australian towns and cities usually have remained well within a level that the government deems to be safe.

On the other hand, because of the health risks associated with high concentrations of nitrogen oxides, volatile organic compounds, and particulate matter, particularly in urban centers, the Australian government has begun to implement measures to reduce emissions of those pollutants. Approximately 80 percent of the nitrogen dioxide emissions in Australian cities come from motor vehicle exhaust [***34***].

Vehicle emissions in Australia are regulated under the Motor Vehicle Standards Act of 1989. The most stringent emissions standards for new vehicles were set in December 1999, based on the schedule of vehicle standards used in the EU. According to the new Australian Design Rule 79/00, Euro 2 standards for all new light-duty vehicles were phased in according to weight class and fuel type, starting in 2002. Rule 79/01 applies the Euro 3 standard for all new light-duty gasoline-powered vehicles starting in 2005 and the Euro 4 standard for all new light-duty diesel-powered vehicles starting in 2006. Rules 80/00 and 80/01 similarly phase in Euro 3 and Euro 4 emissions standards for new medium- and heavy-duty vehicles.

The high sulfur content of gasoline and diesel in Australia was identified as a particular problem for the effective operation of engine catalysts needed to meet tighter emission standards. In May 2001, the Australian government announced the first fuel quality standards to be adopted under the Fuel Quality Standards Act of 2000. Standards for gasoline and diesel began in 2002, in order to ensure compatibility between the fuels and vehicle emissions control technologies.

Japan

In Japan, the regulation of sulfur oxides and other particulate emissions from fuel combustion began after the passage of the Air Pollution Control Law of 1968. Emissions standards were established by order of the Prime Minister's Office and were last amended in 1998. Limit values for sulfur oxide emissions from stationary sources vary according to the geographic location of the facility and height of the exhaust stack, and nitrogen oxide emission limit values vary according to boiler or furnace type. Sulfur content limits for fuels were included under the Air Pollution Control Law by amendments in 1995 and have been in force since 1996. Vehicle emissions standards for nitrogen oxides, carbon monoxide, and hydrocarbons were also established by the Air Pollution Control Law and by the Automobile Nitrogen Oxide Law of 1992.

China

While emissions of sulfur dioxide, nitrogen oxides, and particulate matter have either declined or slowed in most industrialized countries, many developing countries are experiencing rapid growth in energy-related pollution. Issues of most pressing concern involve growing sulfur dioxide emissions and acid rain from coal-fired power plants and increasing levels of smog and particulate matter in urban areas caused by 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, due to limited funding and inadequate means for measuring emissions levels and enforcing standards [***35***]. 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.

According to a report by the World Bank, 16 of the world's 20 most polluted cities are in China [***36***]. Sulfur dioxide and soot caused by coal combustion are two major air pollutants, resulting in the formation of acid rain, which now falls on about 30 percent of China's total land area [***37***]. Ninety percent of the country's sulfur dioxide emissions are attributed to coal-fired boilers, and the government is focusing regulation on sulfur dioxide emissions from power generation and large industrial facilities [***38***].

In 1982 the Chinese government introduced a sulfur dioxide pollution levy, which became the cornerstone of national sulfur dioxide control. The levy system has proven to be only modestly successful at controlling emissions, because it is applied only to medium-sized and large sources, it appears to be set too low to encourage significant sulfur dioxide abatement, and the fee is rarely used for reinvestment in new abatement activities. To improve the system, the levy was changed in 2000 from a fee based on excess emissions to a charge on total emissions. Moreover, in 2002, China implemented a new coal policy, which is expected to reduce sulfur dioxide emissions nationwide by 10 percent from 2000 levels by 2005, and by 20 percent within "control zones" with high pollution, including Beijing, Shanghai, Tianjin, and 197 other cities [***39***]. The control zones account for 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 [***40***]. Smaller facilities must use low-sulfur coal or cleaner fuel alternatives.

In a parallel effort to encourage a switch to cleaner burning fuels, the government has introduced a tax on high-sulfur coals. In Beijing, officials aiming to phase out coal from the city center have established 40 "coal-free zones" and have made plans to construct natural gas pipelines. Similar efforts are underway in other major Chinese cities. 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 cross-provincial border trading scheme. Rules and a timetable for the pilot trading program have not yet been developed.

China is also moving toward adopting Euro 2 emissions standards for light-duty and heavy-duty vehicles. Beijing will be the first Chinese city to implement the new national standards, requiring that all new light-duty and heavy-duty vehicles sold in Beijing after January 1, 2003, comply with the Euro 2 standards. In an additional effort to reduce air pollution in the city, the municipal government is ordering city vehicles to convert to liquefied petroleum gas and natural gas.

India

Urban air quality in India ranks among the world's poorest [***41***]. 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, and the sulfur content of motor fuels sold in the four metro areas has also been restricted to 500 parts per million since 2001, in order to be compatible with the tighter vehicle emissions standards. Since January 2000, motor fuel sulfur content in all other regions of the country has been limited to 2,500 parts per million.

The measures taken to reduce vehicle emissions in New Delhi have been more controversial. In 1998, India's

Supreme Court ordered all the city's buses to be run on compressed natural gas by March 31, 2001. Compliance was to be achieved either by converting existing diesel engines or by replacing the buses themselves. Only 200 compressed natural gas buses were available by the initial deadline, however (out of a total fleet of 12,000), and protests ensued as all other buses were banned from use [**42**]. To ease the transition for both bus owners and commuters, the Delhi government is now allowing a gradual phaseout of the existing diesel bus fleet [**43**].

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 [**44**].

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Appendix A

Reference Case Projections:

- World Energy Consumption
- Gross Domestic Product
- Carbon Dioxide Emissions
- World Population

Table A1. World Total Energy Consumption by Region, Reference Case, 1990-2025
(Quadrillion Btu)

Region/Country	History			Projections					Average Annual Percent Change, 2001-2025
	1990	2000	2001	2005	2010	2015	2020	2025	
Industrialized Countries									
North America	**100.6**	**118.7**	**115.6**	**124.6**	**137.2**	**148.7**	**159.4**	**171.4**	**1.7**
United States[a]	84.6	99.3	97.0	103.2	113.3	121.9	130.1	139.1	1.5
Canada	11.0	13.2	12.5	14.2	15.3	16.0	16.5	17.1	1.3
Mexico	5.0	6.2	6.0	7.2	8.6	10.8	12.8	15.3	4.0
Western Europe	**59.9**	**66.8**	**68.2**	**69.1**	**72.1**	**74.7**	**77.3**	**80.5**	**0.7**
United Kingdom	9.3	9.8	9.8	9.9	10.4	10.8	11.2	11.6	0.7
France	8.8	10.4	10.5	11.0	11.6	12.1	13.0	13.8	1.1
Germany	14.8	14.2	14.4	14.5	14.9	15.3	15.9	16.5	0.6
Italy	7.0	8.0	8.1	8.2	8.6	9.0	9.5	9.9	0.8
Netherlands	3.4	3.9	4.2	4.3	4.5	4.7	4.9	5.1	0.7
Other Western Europe	16.6	20.6	21.1	21.2	22.1	22.7	22.8	23.6	0.5
Industrialized Asia	**22.3**	**27.5**	**27.7**	**28.8**	**30.8**	**32.8**	**34.4**	**36.4**	**1.1**
Japan	17.9	21.8	21.9	22.4	23.8	25.2	26.0	27.1	0.9
Australia/New Zealand	4.4	5.7	5.8	6.4	7.0	7.7	8.3	9.3	2.0
Total Industrialized	**182.8**	**213.0**	**211.5**	**222.5**	**240.1**	**256.2**	**271.1**	**288.3**	**1.3**
EE/FSU									
Former Soviet Union	60.7	40.8	41.9	49.2	52.7	57.1	60.6	64.4	1.8
Eastern Europe	15.6	11.3	11.4	11.9	13.1	14.5	16.1	17.9	1.9
Total EE/FSU	**76.3**	**52.2**	**53.3**	**61.1**	**65.9**	**71.6**	**76.7**	**82.3**	**1.8**
Developing Countries									
Developing Asia	**52.5**	**80.5**	**85.0**	**92.5**	**110.1**	**130.5**	**151.9**	**174.6**	**3.0**
China	27.0	37.0	39.7	43.2	54.4	65.5	77.6	90.8	3.5
India	7.8	12.7	12.8	14.1	16.9	20.1	23.6	27.4	3.2
South Korea	3.8	7.9	8.1	9.0	10.6	12.0	13.0	13.9	2.3
Other Asia	13.9	23.0	24.5	26.2	28.2	33.0	37.7	42.5	2.3
Middle East	**13.1**	**20.3**	**20.8**	**21.4**	**25.0**	**28.3**	**32.0**	**36.0**	**2.3**
Turkey	2.0	3.0	2.9	3.6	4.2	4.7	5.3	5.9	3.0
Other Middle East	11.1	17.3	17.9	17.8	20.8	23.6	26.7	30.1	2.2
Africa	**9.3**	**11.9**	**12.4**	**13.3**	**14.4**	**16.1**	**18.0**	**20.0**	**2.0**
Central and South America	**14.4**	**21.0**	**20.9**	**22.7**	**25.2**	**29.0**	**33.4**	**39.0**	**2.6**
Brazil	6.0	9.0	8.8	9.4	10.8	12.6	14.5	16.5	2.7
Other Central/South America	8.5	12.0	12.2	13.3	14.3	16.4	19.0	22.5	2.6
Total Developing	**89.3**	**133.8**	**139.2**	**149.8**	**174.7**	**203.8**	**235.3**	**269.6**	**2.8**
Total World	**348.4**	**398.9**	**403.9**	**433.3**	**480.6**	**531.7**	**583.0**	**640.1**	**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 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table A1; and System for the Analysis of Global Energy Markets (2003).

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	2005	2010	2015	2020	2025	
Industrialized Countries									
North America									
Oil	40.4	46.3	45.9	48.3	54.2	59.7	64.3	69.3	1.7
Natural Gas	23.1	28.8	27.6	30.6	34.0	37.9	42.0	46.9	2.2
Coal	20.7	24.5	23.9	24.9	27.3	28.7	30.0	31.8	1.2
Nuclear	6.9	8.7	8.9	9.4	9.6	9.7	9.7	9.5	0.3
Other	9.5	10.6	9.4	11.3	12.0	12.7	13.4	13.9	1.7
Total	**100.6**	**118.7**	**115.6**	**124.6**	**137.2**	**148.7**	**159.4**	**171.4**	**1.7**
Western Europe									
Oil	25.8	28.5	28.9	29.2	29.7	30.3	30.6	31.6	0.4
Natural Gas	9.7	14.9	15.1	15.9	17.5	20.1	23.4	26.4	2.4
Coal	12.4	8.4	8.6	8.3	8.2	7.5	6.8	6.7	-1.0
Nuclear	7.4	8.8	9.1	8.9	9.1	8.8	8.1	6.9	-1.1
Other	4.5	6.0	6.1	6.8	7.5	8.0	8.4	8.8	1.5
Total	**59.9**	**66.8**	**68.2**	**69.1**	**72.1**	**74.7**	**77.3**	**80.5**	**0.7**
Industrialized Asia									
Oil	12.1	13.2	13.0	13.5	14.3	15.1	15.8	16.7	1.1
Natural Gas	2.5	4.0	4.1	4.4	4.6	5.0	5.3	5.9	1.5
Coal	4.2	5.7	5.9	5.8	6.3	6.7	7.0	7.4	0.9
Nuclear	2.0	3.0	3.2	3.2	3.6	3.9	4.0	3.9	0.9
Other	1.6	1.6	1.6	1.9	2.0	2.1	2.3	2.4	1.7
Total	**22.3**	**27.5**	**27.7**	**28.8**	**30.8**	**32.8**	**34.4**	**36.4**	**1.1**
Total Industrialized									
Oil	78.2	88.1	87.8	90.9	98.2	105.1	110.7	117.6	1.2
Natural Gas	35.4	47.7	46.8	50.9	56.1	63.0	70.7	79.2	2.2
Coal	37.3	38.6	38.5	39.1	41.9	42.9	43.7	45.9	0.7
Nuclear	16.3	20.5	21.2	21.5	22.3	22.3	21.8	20.4	-0.2
Other	15.6	18.2	17.1	20.0	21.6	22.8	24.0	25.2	1.6
Total	**182.8**	**213.0**	**211.5**	**222.5**	**240.1**	**256.2**	**271.1**	**288.3**	**1.3**
EE/FSU									
Oil	21.0	10.9	11.0	12.6	14.2	15.0	16.5	18.3	2.1
Natural Gas	28.8	23.3	23.8	27.9	31.9	36.9	42.0	47.0	2.9
Coal	20.8	12.2	12.4	13.7	12.7	12.5	11.2	10.2	-0.8
Nuclear	2.9	3.0	3.1	3.3	3.3	3.3	3.0	2.6	-0.7
Other	2.8	3.0	3.2	3.6	3.7	3.9	4.0	4.1	1.1
Total	**76.3**	**52.2**	**53.3**	**61.1**	**65.9**	**71.6**	**76.7**	**82.3**	**1.8**
Developing Countries									
Developing Asia									
Oil	16.1	30.2	30.7	33.5	38.9	45.8	53.8	61.9	3.0
Natural Gas	3.2	6.9	7.9	9.0	10.9	15.1	18.6	22.7	4.5
Coal	29.1	37.1	39.4	41.3	49.4	56.6	65.0	74.0	2.7
Nuclear	0.9	1.7	1.8	2.6	3.1	4.1	4.5	5.0	4.3
Other	3.2	4.5	5.1	6.1	7.8	8.9	10.0	11.0	3.2
Total	**52.5**	**80.5**	**85.0**	**92.5**	**110.1**	**130.5**	**151.9**	**174.6**	**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			Projections					Average Annual Percent Change, 2001-2025
	1990	2000	2001	2005	2010	2015	2020	2025	
Developing Countries (Continued)									
Middle East									
Oil	8.0	11.0	11.1	11.0	12.7	14.5	16.3	18.4	2.1
Natural Gas	3.9	7.7	8.2	8.4	10.1	11.4	12.9	14.6	2.4
Coal	0.8	1.1	1.1	1.3	1.4	1.5	1.6	1.8	2.1
Nuclear	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	—
Other	0.4	0.5	0.4	0.6	0.8	0.9	1.0	1.1	4.4
Total	**13.1**	**20.3**	**20.8**	**21.4**	**25.0**	**28.3**	**32.0**	**36.0**	**2.3**
Africa									
Oil	4.2	5.2	5.3	5.2	5.6	6.0	6.5	7.1	1.2
Natural Gas	1.5	2.2	2.5	2.6	3.1	3.9	4.8	5.7	3.6
Coal	3.0	3.7	3.8	4.4	4.5	4.9	5.4	5.9	1.8
Nuclear	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	1.1
Other	0.6	0.7	0.8	0.9	1.1	1.2	1.2	1.2	1.9
Total	**9.3**	**11.9**	**12.4**	**13.3**	**14.4**	**16.1**	**18.0**	**20.0**	**2.0**
Central and South America									
Oil	7.7	10.6	10.5	11.0	12.2	13.7	15.3	17.4	2.1
Natural Gas	2.2	3.6	3.8	4.2	5.3	7.0	9.5	12.6	5.1
Coal	0.6	0.9	0.8	0.9	1.0	1.1	1.2	1.2	1.9
Nuclear	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.6
Other	3.9	5.9	5.6	6.3	6.5	6.9	7.1	7.5	1.2
Total	**14.4**	**21.0**	**20.9**	**22.7**	**25.2**	**29.0**	**33.4**	**39.0**	**2.6**
Total Developing Countries									
Oil	35.9	56.9	57.6	60.7	69.3	79.9	91.9	104.8	2.5
Natural Gas	10.8	20.4	22.4	24.2	29.5	37.4	45.8	55.6	3.9
Coal	33.5	42.8	45.1	47.9	56.3	64.2	73.2	82.9	2.6
Nuclear	1.1	2.0	2.2	3.0	3.5	4.6	5.0	5.6	4.0
Other	8.0	11.6	11.8	14.0	16.2	17.8	19.3	20.8	2.4
Total	**89.3**	**133.8**	**139.2**	**149.8**	**174.7**	**203.8**	**235.3**	**269.6**	**2.8**
Total World									
Oil	135.1	155.9	156.5	164.2	181.7	200.1	219.2	240.7	1.8
Natural Gas	75.0	91.4	93.1	103.0	117.5	137.3	158.5	181.8	2.8
Coal	91.6	93.6	95.9	100.7	110.9	119.6	128.1	139.0	1.6
Nuclear	20.3	25.5	26.4	27.8	29.1	30.3	29.9	28.6	0.3
Other	26.4	32.8	32.2	37.6	41.5	44.5	47.3	50.0	1.9
Total	**348.4**	**398.9**	**403.9**	**433.3**	**480.6**	**531.7**	**583.0**	**640.1**	**1.9**

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 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table A1; and System for the Analysis of Global Energy Markets (2003).

Table A3. World Gross Domestic Product (GDP) by Region, Reference Case, 1990-2025
(Billion 1997 Dollars)

Region/Country	History			Projections					Average Annual Percent Change, 2001-2025
	1990	2000	2001	2005	2010	2015	2020	2025	
Industrialized Countries									
North America	**7,723**	**10,555**	**10,588**	**11,947**	**14,192**	**16,645**	**19,246**	**22,218**	**3.1**
United States[a]	6,836	9,370	9,394	10,563	12,497	14,566	16,770	19,285	3.0
Canada	555	731	742	848	978	1,112	1,253	1,406	2.7
Mexico	332	453	452	536	717	967	1,223	1,528	5.2
Western Europe	**7,597**	**9,312**	**9,460**	**10,378**	**11,694**	**13,125**	**14,724**	**16,395**	**2.3**
United Kingdom	1,146	1,439	1,471	1,621	1,845	2,059	2,281	2,528	2.3
France	1,299	1,564	1,593	1,747	1,974	2,214	2,497	2,781	2.3
Germany	1,879	2,257	2,274	2,480	2,780	3,100	3,450	3,811	2.2
Italy	1,079	1,241	1,263	1,385	1,534	1,724	1,950	2,168	2.3
Netherlands	317	422	427	465	525	591	667	754	2.4
Other Western Europe	1,877	2,389	2,432	2,681	3,036	3,437	3,880	4,353	2.5
Industrialized Asia	**4,054**	**4,922**	**4,920**	**5,280**	**5,891**	**6,512**	**7,153**	**7,828**	**2.0**
Japan	3,673	4,390	4,376	4,658	5,164	5,662	6,162	6,680	1.8
Australia/New Zealand	381	532	545	622	728	850	991	1,148	3.2
Total Industrialized	**19,374**	**24,789**	**24,967**	**27,606**	**31,777**	**36,282**	**41,123**	**46,441**	**2.6**
EE/FSU									
Former Soviet Union	1,009	617	654	770	957	1,152	1,360	1,600	3.8
Eastern Europe	348	380	390	458	561	689	853	1,044	4.2
Total EE/FSU	**1,357**	**997**	**1,044**	**1,228**	**1,518**	**1,841**	**2,213**	**2,645**	**4.0**
Developing Countries									
Developing Asia	**1,739**	**3,393**	**3,525**	**4,433**	**5,856**	**7,528**	**9,513**	**11,752**	**5.1**
China	427	1,119	1,201	1,599	2,191	2,949	3,935	5,085	6.2
India	268	495	521	640	832	1,077	1,390	1,775	5.2
South Korea	297	539	557	708	927	1,126	1,311	1,498	4.2
Other Asia	748	1,241	1,247	1,486	1,906	2,376	2,877	3,394	4.3
Middle East	**379**	**590**	**581**	**663**	**808**	**970**	**1,154**	**1,359**	**3.6**
Turkey	140	200	185	219	271	330	399	474	4.0
Other Middle East	239	390	395	444	538	640	755	886	3.4
Africa	**405**	**596**	**617**	**715**	**862**	**1,027**	**1,216**	**1,426**	**3.6**
Central and South America	**1,136**	**1,497**	**1,505**	**1,618**	**1,983**	**2,446**	**3,040**	**3,811**	**3.9**
Brazil	674	852	865	954	1,158	1,421	1,755	2,175	3.9
Other Central/South America	462	645	639	664	825	1,025	1,285	1,635	4.0
Total Developing	**3,660**	**6,077**	**6,228**	**7,430**	**9,510**	**11,971**	**14,923**	**18,348**	**4.6**
Total World	**24,392**	**31,863**	**32,239**	**36,263**	**42,804**	**50,095**	**58,259**	**67,434**	**3.1**

[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: Global Insight, Inc., *World Economic Outlook*, Vol. 1 (Lexington, MA, Third Quarter 2002), and Energy Information Administration, *Annual Energy Outlook 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), 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 2005	Projections 2010	Projections 2015	Projections 2020	Projections 2025	Average Annual Percent Change, 2001-2025
Industrialized Countries									
North America	**20.4**	**23.8**	**23.5**	**24.8**	**27.9**	**30.7**	**33.1**	**35.7**	**1.8**
United States[a]	17.0	19.7	19.6	20.5	23.0	25.2	27.1	29.2	1.7
Canada	1.7	2.1	1.9	2.1	2.2	2.3	2.4	2.4	1.0
Mexico	1.7	2.0	1.9	2.2	2.7	3.2	3.6	4.1	3.2
Western Europe	**12.5**	**13.8**	**14.0**	**14.1**	**14.4**	**14.6**	**14.8**	**15.3**	**0.4**
United Kingdom	1.8	1.7	1.7	1.7	1.8	1.9	2.0	2.0	0.7
France	1.8	2.0	2.0	2.0	2.1	2.1	2.1	2.2	0.3
Germany	2.7	2.8	2.8	2.8	2.9	3.0	3.0	3.1	0.4
Italy	1.9	1.9	1.9	1.9	1.9	2.0	2.0	2.1	0.5
Netherlands	0.7	0.9	0.9	0.9	1.0	1.0	1.0	1.0	0.6
Other Western Europe	3.6	4.6	4.7	4.7	4.7	4.7	4.7	4.9	0.2
Industrialized Asia	**6.0**	**6.5**	**6.4**	**6.7**	**7.1**	**7.5**	**7.8**	**8.3**	**1.1**
Japan	5.1	5.5	5.4	5.5	5.8	6.1	6.3	6.5	0.8
Australia/New Zealand	0.8	1.0	1.0	1.1	1.3	1.4	1.6	1.7	2.3
Total Industrialized	**38.8**	**44.1**	**43.9**	**45.6**	**49.3**	**52.9**	**55.8**	**59.3**	**1.3**
EE/FSU									
Former Soviet Union	8.4	3.8	3.9	4.5	5.1	5.3	5.7	6.2	2.0
Eastern Europe	1.6	1.4	1.4	1.5	1.7	2.0	2.2	2.5	2.5
Total EE/FSU	**10.0**	**5.2**	**5.3**	**6.1**	**6.8**	**7.2**	**7.9**	**8.8**	**2.1**
Developing Countries									
Developing Asia	**7.6**	**14.5**	**14.8**	**16.1**	**18.7**	**22.0**	**25.9**	**29.8**	**3.0**
China	2.3	4.8	5.0	5.5	6.5	7.7	9.4	10.9	3.3
India	1.2	2.1	2.1	2.3	2.8	3.5	4.5	5.5	4.0
South Korea	1.0	2.1	2.1	2.4	2.8	3.0	3.1	3.3	1.8
Other Asia	3.1	5.5	5.5	6.0	6.7	7.8	8.9	10.2	2.6
Middle East	**3.8**	**5.3**	**5.4**	**5.4**	**6.2**	**7.0**	**7.9**	**8.9**	**2.1**
Turkey	0.5	0.7	0.6	0.8	0.9	1.1	1.2	1.3	3.1
Other Middle East	3.4	4.7	4.7	4.6	5.2	6.0	6.7	7.6	2.0
Africa	**2.1**	**2.5**	**2.6**	**2.5**	**2.7**	**2.9**	**3.2**	**3.5**	**1.2**
Central and South America	**3.7**	**5.2**	**5.2**	**5.4**	**6.0**	**6.7**	**7.5**	**8.5**	**2.1**
Brazil	1.5	2.2	2.2	2.4	2.7	3.0	3.4	3.9	2.4
Other Central/South America	2.3	3.0	3.0	3.0	3.3	3.7	4.1	4.6	1.8
Total Developing	**17.3**	**27.6**	**27.9**	**29.4**	**33.5**	**38.7**	**44.5**	**50.7**	**2.5**
Total World	**66.1**	**76.9**	**77.1**	**81.1**	**89.7**	**98.8**	**108.2**	**118.8**	**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 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table A21; and System for the Analysis of Global Energy Markets (2003).

Table A5. World Natural Gas Consumption by Region, Reference Case, 1990-2025
(Trillion Cubic Feet)

Region/Country	History 1990	History 2000	History 2001	Projections 2005	Projections 2010	Projections 2015	Projections 2020	Projections 2025	Average Annual Percent Change, 2001-2025
Industrialized Countries									
North America	**22.5**	**28.1**	**26.9**	**29.8**	**33.1**	**36.9**	**40.9**	**45.6**	**2.2**
United States[a]	19.2	23.5	22.6	24.6	27.1	29.5	32.1	34.9	1.8
Canada	2.4	3.3	2.9	3.4	3.7	4.1	4.4	5.0	2.3
Mexico	0.9	1.4	1.4	1.8	2.4	3.2	4.3	5.7	6.1
Western Europe	**10.1**	**14.6**	**14.8**	**15.5**	**17.1**	**19.7**	**22.9**	**25.9**	**2.4**
United Kingdom	2.1	3.4	3.3	3.5	3.7	4.4	4.8	5.0	1.7
France	1.0	1.4	1.5	1.5	1.6	1.9	2.6	3.2	3.3
Germany	2.7	3.2	3.3	3.4	3.6	4.1	5.3	6.2	2.6
Italy	1.7	2.5	2.5	2.6	2.7	3.1	3.4	3.6	1.5
Netherlands	1.5	1.7	1.8	1.9	1.9	2.0	2.2	2.3	1.2
Other Western Europe	1.2	2.3	2.4	2.6	3.6	4.2	4.6	5.5	3.5
Industrialized Asia	**2.6**	**3.8**	**3.9**	**4.2**	**4.4**	**4.7**	**5.1**	**5.6**	**1.5**
Japan	1.9	2.8	2.8	3.0	3.2	3.3	3.4	3.6	1.0
Australia/New Zealand	0.8	1.0	1.1	1.2	1.2	1.4	1.6	2.0	2.7
Total Industrialized	**35.2**	**46.4**	**45.6**	**49.5**	**54.6**	**61.3**	**68.8**	**77.0**	**2.2**
EE/FSU									
Former Soviet Union	25.0	20.5	20.8	24.4	27.3	31.2	35.0	38.6	2.6
Eastern Europe	3.1	2.4	2.7	3.1	4.1	5.2	6.4	7.8	4.6
Total EE/FSU	**28.1**	**23.0**	**23.5**	**27.5**	**31.4**	**36.4**	**41.4**	**46.4**	**2.9**
Developing Countries									
Developing Asia	**3.0**	**6.6**	**7.5**	**8.6**	**10.4**	**14.3**	**17.7**	**21.6**	**4.5**
China	0.5	1.0	1.0	1.4	2.3	3.8	4.5	6.1	7.9
India	0.4	0.8	0.8	1.3	1.8	2.5	3.1	3.4	6.1
South Korea	0.1	0.7	0.7	0.8	1.2	1.5	1.7	1.9	3.9
Other Asia	2.0	4.2	4.9	5.0	5.2	6.6	8.4	10.2	3.1
Middle East	**3.7**	**7.3**	**7.9**	**8.0**	**9.6**	**10.9**	**12.3**	**13.9**	**2.4**
Turkey	0.1	0.5	0.6	0.8	0.9	1.0	1.2	1.3	3.7
Other Middle East	3.6	6.8	7.3	7.2	8.8	9.8	11.1	12.6	2.3
Africa	**1.4**	**2.0**	**2.3**	**2.4**	**2.9**	**3.6**	**4.4**	**5.3**	**3.6**
Central and South America	**2.0**	**3.3**	**3.5**	**3.9**	**5.0**	**6.5**	**8.8**	**11.7**	**5.2**
Brazil	0.1	0.3	0.3	0.6	1.2	1.9	2.6	3.4	10.1
Other Central/South America	1.9	3.0	3.2	3.3	3.7	4.6	6.2	8.3	4.1
Total Developing	**10.1**	**19.3**	**21.2**	**23.0**	**27.9**	**35.3**	**43.3**	**52.5**	**3.9**
Total World	**73.4**	**88.7**	**90.3**	**100.0**	**113.9**	**133.0**	**153.5**	**175.9**	**2.8**

[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 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table A13; and System for the Analysis of Global Energy Markets (2003).

Table A6. World Coal Consumption by Region, Reference Case, 1990-2025
(Million Short Tons)

Region/Country	History 1990	History 2000	History 2001	Projections 2005	Projections 2010	Projections 2015	Projections 2020	Projections 2025	Average Annual Percent Change, 2001-2025
Industrialized Countries									
North America	**971**	**1,168**	**1,148**	**1,200**	**1,322**	**1,391**	**1,464**	**1,553**	**1.3**
United States[a]	903	1,084	1,060	1,106	1,218	1,282	1,358	1,444	1.3
Canada	59	69	73	80	86	85	78	76	0.2
Mexico	9	15	15	14	18	24	28	33	3.3
Western Europe	**894**	**559**	**574**	**551**	**546**	**497**	**447**	**446**	**-1.0**
United Kingdom	119	64	71	64	64	58	53	53	-1.2
France	35	25	21	17	17	10	7	7	-4.6
Germany	528	264	265	265	264	237	203	203	-1.1
Italy	25	20	22	22	22	20	18	18	-0.8
Netherlands	15	14	23	16	13	12	12	12	-2.9
Other Western Europe	172	172	172	166	166	160	154	154	-0.5
Industrialized Asia	**231**	**303**	**312**	**315**	**344**	**361**	**378**	**400**	**1.0**
Japan	125	160	166	160	168	180	187	198	0.7
Australia/New Zealand	106	143	147	155	176	181	191	202	1.3
Total Industrialized	**2,095**	**2,029**	**2,034**	**2,066**	**2,213**	**2,250**	**2,289**	**2,399**	**0.7**
EE/FSU									
Former Soviet Union	848	421	446	553	507	511	457	415	-0.3
Eastern Europe	528	390	382	318	304	283	254	234	-2.0
Total EE/FSU	**1,376**	**811**	**828**	**871**	**811**	**794**	**711**	**649**	**-1.0**
Developing Countries									
Developing Asia	**1,590**	**1,959**	**2,084**	**2,179**	**2,616**	**2,998**	**3,452**	**3,940**	**2.7**
China	1,124	1,282	1,383	1,442	1,811	2,115	2,511	2,917	3.2
India	242	359	360	382	431	472	510	580	2.0
South Korea	49	72	76	74	93	104	110	115	1.7
Other Asia	175	246	265	280	281	307	322	330	0.9
Middle East	**66**	**94**	**95**	**109**	**117**	**129**	**139**	**149**	**1.9**
Turkey	60	80	81	89	94	103	109	121	1.7
Other Middle East	6	14	14	20	23	26	29	28	3.1
Africa	**152**	**187**	**191**	**220**	**226**	**247**	**270**	**294**	**1.8**
Central and South America	**27**	**34**	**32**	**37**	**41**	**46**	**47**	**50**	**1.9**
Brazil	17	21	21	22	25	31	31	36	2.3
Other Central/South America	10	13	11	15	16	16	16	14	1.1
Total Developing	**1,835**	**2,275**	**2,401**	**2,545**	**3,000**	**3,420**	**3,908**	**4,433**	**2.6**
Total World	**5,307**	**5,115**	**5,263**	**5,481**	**6,023**	**6,464**	**6,909**	**7,482**	**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 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table A16; and System for the Analysis of Global Energy Markets (2003).

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	2005	2010	2015	2020	2025	
Industrialized Countries									
North America	**649**	**830**	**850**	**894**	**912**	**918**	**923**	**902**	**0.3**
United States[a]	577	754	769	793	800	805	807	807	0.2
Canada	69	69	73	92	103	104	106	85	0.6
Mexico	3	8	8	9	9	9	10	10	0.8
Western Europe	**703**	**845**	**870**	**856**	**869**	**845**	**784**	**666**	**-1.1**
United Kingdom	59	82	86	73	72	46	39	36	-3.6
France	298	394	401	406	427	432	437	425	0.2
Germany	145	161	163	166	145	142	100	45	-5.2
Italy	0	0	0	0	0	0	0	0	—
Netherlands	3	4	4	4	4	4	0	0	-100.0
Other Western Europe	198	204	217	206	220	222	207	161	-1.3
Industrialized Asia	**192**	**294**	**309**	**313**	**352**	**380**	**389**	**386**	**0.9**
Japan	192	294	309	313	352	380	389	386	0.9
Australia/New Zealand	0	0	0	0	0	0	0	0	—
Total Industrialized	**1,544**	**1,969**	**2,029**	**2,063**	**2,133**	**2,143**	**2,096**	**1,954**	**-0.2**
EE/FSU									
Former Soviet Union	201	204	210	217	228	223	188	154	-1.3
Eastern Europe	54	67	72	80	76	78	86	86	0.7
Total EE/FSU	**256**	**270**	**282**	**297**	**304**	**301**	**274**	**240**	**-0.7**
Developing Countries									
Developing Asia	**88**	**171**	**178**	**254**	**301**	**401**	**436**	**485**	**9.7**
China	0	16	17	57	66	129	131	154	9.7
India	6	14	18	21	27	40	46	49	4.2
South Korea	50	104	107	136	145	169	192	225	3.2
Other Asia	32	37	36	40	63	63	67	57	1.9
Middle East	**0**	**0**	**0**	**5**	**5**	**12**	**13**	**19**	**—**
Turkey	0	0	0	0	0	0	0	6	—
Other Middle East	0	0	0	5	5	12	13	13	—
Africa	**8**	**13**	**11**	**16**	**14**	**14**	**14**	**14**	**1.1**
Central and South America	**9**	**11**	**21**	**17**	**18**	**26**	**25**	**25**	**0.8**
Brazil	2	5	14	11	12	20	21	21	1.6
Other Central/South America	7	6	7	6	6	6	4	4	-1.8
Total Developing	**105**	**195**	**209**	**292**	**338**	**453**	**488**	**543**	**4.1**
Total World	**1,905**	**2,434**	**2,521**	**2,652**	**2,775**	**2,897**	**2,858**	**2,737**	**0.3**

[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. 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 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table A8; and System for the Analysis of Global Energy Markets (2003).

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	2005	2010	2015	2020	2025	
Industrialized Countries									
North America	**9.5**	**10.6**	**9.4**	**11.3**	**12.0**	**12.7**	**13.4**	**13.9**	**1.7**
United States[a]	6.0	6.4	5.5	7.0	7.5	8.0	8.5	8.9	2.0
Canada	3.1	3.8	3.5	3.8	4.0	4.2	4.3	4.5	1.1
Mexico	0.3	0.5	0.4	0.5	0.5	0.6	0.6	0.6	1.5
Western Europe	**4.5**	**6.0**	**6.1**	**6.8**	**7.5**	**8.0**	**8.4**	**8.8**	**1.5**
United Kingdom	0.1	0.1	0.1	0.3	0.4	0.4	0.5	0.6	8.4
France	0.6	0.7	0.8	0.7	0.8	0.9	1.0	1.0	1.2
Germany	0.3	0.4	0.5	0.5	0.6	0.8	0.9	0.9	2.9
Italy	0.4	0.6	0.6	1.1	1.2	1.2	1.3	1.3	3.2
Netherlands	0.0	0.1	0.1	0.2	0.2	0.3	0.3	0.4	8.5
Other Western Europe	3.2	4.1	4.1	4.1	4.4	4.4	4.4	4.5	0.4
Industrialized Asia	**1.6**	**1.6**	**1.6**	**1.9**	**2.0**	**2.1**	**2.3**	**2.4**	**1.7**
Japan	1.1	1.1	1.1	1.3	1.4	1.5	1.6	1.8	1.8
Australia/New Zealand	0.4	0.5	0.5	0.6	0.6	0.6	0.6	0.7	1.3
Total Industrialized	**15.6**	**18.2**	**17.1**	**20.0**	**21.6**	**22.8**	**24.0**	**25.2**	**1.6**
EE/FSU									
Former Soviet Union	2.4	2.3	2.5	2.8	2.9	2.9	3.0	3.0	0.8
Eastern Europe	0.4	0.6	0.6	0.8	0.9	0.9	1.0	1.1	2.2
Total EE/FSU	**2.8**	**3.0**	**3.2**	**3.6**	**3.7**	**3.9**	**4.0**	**4.1**	**1.1**
Developing Countries									
Developing Asia	**3.2**	**4.5**	**5.1**	**6.1**	**7.8**	**8.9**	**10.0**	**11.0**	**3.2**
China	1.3	2.3	2.8	3.2	4.6	5.2	5.9	6.4	3.6
India	0.7	0.8	0.8	0.9	1.1	1.2	1.4	1.5	2.6
South Korea	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	7.3
Other Asia	1.1	1.4	1.5	1.9	2.1	2.3	2.6	2.8	2.7
Middle East	**0.4**	**0.5**	**0.4**	**0.6**	**0.8**	**0.9**	**1.0**	**1.1**	**4.4**
Turkey	0.2	0.3	0.3	0.4	0.5	0.6	0.7	0.7	4.6
Other Middle East	0.1	0.1	0.1	0.2	0.3	0.3	0.3	0.4	3.9
Africa	**0.6**	**0.7**	**0.8**	**0.9**	**1.1**	**1.2**	**1.2**	**1.2**	**1.9**
Central and South America	**3.9**	**5.9**	**5.6**	**6.3**	**6.5**	**6.9**	**7.1**	**7.5**	**1.2**
Brazil	2.2	3.3	2.9	3.2	3.4	3.5	3.6	3.7	1.0
Other Central/South America	1.7	2.6	2.7	3.1	3.1	3.3	3.5	3.7	1.4
Total Developing	**8.0**	**11.6**	**11.8**	**14.0**	**16.2**	**17.8**	**19.3**	**20.8**	**2.4**
Total World	**26.4**	**32.8**	**32.2**	**37.6**	**41.5**	**44.5**	**47.3**	**50.0**	**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 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table A1; and System for the Analysis of Global Energy Markets (2003).

Table A9. World Net Electricity Consumption by Region, Reference Case, 1990-2025
(Billion Kilowatthours)

Region/Country	History			Projections					Average Annual Percent Change, 2001-2025
	1990	2000	2001	2005	2010	2015	2020	2025	
Industrialized Countries									
North America	**3,369**	**4,297**	**4,293**	**4,422**	**4,972**	**5,512**	**6,042**	**6,628**	**1.8**
United States[a]	2,827	3,605	3,602	3,684	4,101	4,481	4,850	5,252	1.6
Canada	435	510	504	539	601	662	720	784	1.9
Mexico	107	182	187	198	270	369	473	592	4.9
Western Europe	**2,069**	**2,487**	**2,540**	**2,664**	**2,902**	**3,156**	**3,438**	**3,708**	**1.6**
United Kingdom	286	341	346	358	387	414	441	469	1.3
France	324	406	415	446	482	519	572	626	1.7
Germany	489	502	507	528	563	601	646	694	1.3
Italy	222	282	289	305	337	373	413	453	1.9
Netherlands	71	97	99	116	125	135	146	158	2.0
Other Western Europe	676	858	883	911	1,008	1,114	1,220	1,307	1.6
Industrialized Asia	**930**	**1,165**	**1,183**	**1,221**	**1,326**	**1,438**	**1,550**	**1,658**	**1.4**
Japan	765	944	964	989	1,073	1,154	1,229	1,302	1.3
Australia/New Zealand	166	221	219	233	253	284	321	356	2.0
Total Industrialized	**6,368**	**7,950**	**8,016**	**8,307**	**9,200**	**10,106**	**11,030**	**11,994**	**1.7**
EE/FSU									
Former Soviet Union	1,488	1,118	1,135	1,353	1,502	1,648	1,778	1,905	2.2
Eastern Europe	418	385	393	415	481	557	645	737	2.7
Total EE/FSU	**1,906**	**1,504**	**1,528**	**1,768**	**1,982**	**2,204**	**2,423**	**2,642**	**2.3**
Developing Countries									
Developing Asia	**1,259**	**2,542**	**2,730**	**3,103**	**3,851**	**4,697**	**5,634**	**6,604**	**3.7**
China	551	1,189	1,312	1,545	1,966	2,428	2,986	3,596	4.3
India	257	477	497	528	662	802	958	1,104	3.4
South Korea	93	254	270	296	372	443	498	552	3.0
Other Asia	358	621	650	734	850	1,024	1,192	1,352	3.1
Middle East	**263**	**522**	**543**	**558**	**665**	**784**	**914**	**1,056**	**2.8**
Turkey	51	114	113	132	154	177	201	226	2.9
Other Middle East	213	408	430	426	511	607	713	831	2.8
Africa	**286**	**388**	**396**	**442**	**521**	**611**	**705**	**800**	**3.0**
Central and South America	**463**	**724**	**721**	**782**	**925**	**1,081**	**1,302**	**1,577**	**3.3**
Brazil	229	359	336	377	444	524	612	708	3.2
Other Central/South America	234	365	385	405	481	556	690	869	3.5
Total Developing	**2,272**	**4,175**	**4,390**	**4,886**	**5,962**	**7,172**	**8,555**	**10,038**	**3.5**
Total World	**10,546**	**13,629**	**13,934**	**14,960**	**17,144**	**19,482**	**22,009**	**24,673**	**2.4**

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

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Electricity consumption equals generation plus imports minus exports minus distribution losses.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, *Annual Energy Outlook 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table A2; and System for the Analysis of Global Energy Markets (2003).

Table A10. World Carbon Dioxide Emissions by Region, Reference Case, 1990-2025
(Million Metric Tons Carbon Equivalent)

Region/Country	History			Projections					Average Annual Percent Change, 2001-2025
	1990	2000	2001	2005	2010	2015	2020	2025	
Industrialized Countries									
North America	**1,564**	**1,836**	**1,810**	**1,910**	**2,124**	**2,312**	**2,485**	**2,689**	**1.7**
United States[a]	1,352	1,578	1,559	1,624	1,800	1,944	2,082	2,237	1.5
Canada	129	158	155	172	186	194	196	206	1.2
Mexico	84	99	96	114	138	174	207	247	4.0
Western Europe	**931**	**939**	**945**	**950**	**982**	**1,011**	**1,044**	**1,104**	**0.7**
United Kingdom	164	151	153	155	163	172	176	182	0.7
France	102	109	108	106	108	113	122	135	0.9
Germany	271	226	223	224	232	233	241	257	0.6
Italy	113	121	121	124	129	134	140	146	0.8
Netherlands	58	62	68	66	71	72	74	76	0.5
Other Western Europe	223	270	271	276	280	288	291	309	0.6
Industrialized Asia	**349**	**416**	**424**	**437**	**465**	**494**	**518**	**552**	**1.1**
Japan	269	310	316	319	334	353	365	382	0.8
Australia/New Zealand	80	106	109	117	131	142	154	170	1.9
Total Industrialized	**2,844**	**3,191**	**3,179**	**3,296**	**3,572**	**3,817**	**4,048**	**4,346**	**1.3**
EE/FSU									
Former Soviet Union	1,036	638	654	780	825	890	939	995	1.8
Eastern Europe	301	204	202	197	213	230	248	272	1.3
Total EE/FSU	**1,337**	**842**	**856**	**977**	**1,038**	**1,120**	**1,187**	**1,267**	**1.6**
Developing Countries									
Developing Asia	**1,089**	**1,557**	**1,640**	**1,749**	**2,075**	**2,436**	**2,837**	**3,263**	**2.9**
China	617	780	832	888	1,109	1,319	1,574	1,844	3.4
India	153	249	250	272	321	375	435	506	3.0
South Korea	64	116	121	131	156	178	193	206	2.2
Other Asia	256	411	437	459	489	563	635	707	2.0
Middle East	**231**	**344**	**354**	**361**	**420**	**475**	**534**	**601**	**2.2**
Turkey	35	50	50	61	73	83	93	104	3.1
Other Middle East	196	294	304	300	347	392	441	497	2.1
Africa	**179**	**221**	**230**	**244**	**261**	**290**	**326**	**361**	**1.9**
Central and South America	**192**	**262**	**263**	**280**	**319**	**374**	**440**	**523**	**2.9**
Brazil	68	93	95	106	127	152	180	212	3.4
Other Central/South America	124	169	168	174	192	222	260	311	2.6
Total Developing	**1,691**	**2,385**	**2,487**	**2,635**	**3,075**	**3,575**	**4,137**	**4,749**	**2.7**
Total World	**5,872**	**6,417**	**6,522**	**6,908**	**7,685**	**8,512**	**9,372**	**10,361**	**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 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table A19; and System for the Analysis of Global Energy Markets (2003).

Table A11. World Carbon Dioxide Emissions from Oil Use by Region, Reference Case, 1990-2025
(Million Metric Tons Carbon Equivalent)

Region/Country	History			Projections					Average Annual Percent Change, 2001-2025
	1990	2000	2001	2005	2010	2015	2020	2025	
Industrialized Countries									
North America	**716**	**800**	**807**	**835**	**940**	**1,036**	**1,116**	**1,205**	**1.7**
United States[a]	590	659	668	680	764	838	902	971	1.6
Canada	61	70	70	76	81	84	86	89	1.0
Mexico	65	71	68	79	94	113	129	145	3.2
Western Europe	**474**	**505**	**503**	**507**	**516**	**526**	**532**	**548**	**0.4**
United Kingdom	66	63	63	64	67	70	72	74	0.7
France	67	73	73	73	74	76	76	78	0.3
Germany	103	97	95	95	97	100	101	104	0.4
Italy	74	71	71	72	74	76	77	80	0.5
Netherlands	27	27	27	28	28	29	30	31	0.6
Other Western Europe	138	174	174	174	175	175	176	181	0.2
Industrialized Asia	**209**	**219**	**219**	**228**	**241**	**256**	**268**	**283**	**1.1**
Japan	179	182	182	186	195	204	210	220	0.8
Australia/New Zealand	31	37	37	42	47	52	58	64	2.3
Total Industrialized	**1,400**	**1,524**	**1,528**	**1,570**	**1,697**	**1,818**	**1,916**	**2,037**	**1.2**
EE/FSU									
Former Soviet Union	334	149	152	176	199	205	223	244	2.0
Eastern Europe	66	49	49	54	61	69	78	89	2.5
Total EE/FSU	**400**	**199**	**201**	**231**	**260**	**274**	**301**	**333**	**2.1**
Developing Countries									
Developing Asia	**304**	**522**	**533**	**580**	**673**	**793**	**933**	**1,073**	**3.0**
China	94	169	175	194	229	271	330	383	3.3
India	45	76	76	81	100	126	160	195	4.0
South Korea	38	65	67	74	86	93	98	103	1.8
Other Asia	128	211	215	231	259	303	345	391	2.5
Middle East	**155**	**205**	**208**	**208**	**239**	**272**	**307**	**346**	**2.1**
Turkey	17	22	22	27	32	35	39	43	2.8
Other Middle East	137	183	186	180	208	237	267	303	2.0
Africa	**83**	**97**	**100**	**97**	**105**	**112**	**123**	**134**	**1.2**
Central and South America	**145**	**189**	**188**	**197**	**217**	**244**	**274**	**310**	**2.1**
Brazil	57	75	76	83	94	105	121	138	2.5
Other Central/South America	88	114	112	114	124	139	153	172	1.8
Total Developing	**688**	**1,013**	**1,029**	**1,081**	**1,234**	**1,422**	**1,636**	**1,863**	**2.5**
Total World	**2,488**	**2,736**	**2,759**	**2,882**	**3,191**	**3,515**	**3,853**	**4,232**	**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 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table A19; and System for the Analysis of Global Energy Markets (2003).

Table A12. World Carbon Dioxide Emissions from Natural Gas Use by Region, Reference Case, 1990-2025
(Million Metric Tons Carbon Equivalent)

Region/Country	History			Projections					Average Annual Percent Change, 2001-2025
	1990	2000	2001	2005	2010	2015	2020	2025	
Industrialized Countries									
North America	**329**	**410**	**393**	**439**	**488**	**543**	**602**	**672**	**2.3**
United States[a]	280	341	329	361	397	433	472	512	1.9
Canada	35	48	43	50	55	61	65	73	2.3
Mexico	15	21	21	28	36	49	65	87	6.1
Western Europe	**140**	**214**	**218**	**228**	**252**	**290**	**337**	**381**	**2.4**
United Kingdom	30	51	50	54	55	65	70	73	1.6
France	16	22	23	23	25	31	42	53	2.8
Germany	32	45	47	48	53	60	78	91	2.8
Italy	25	37	37	38	41	45	51	54	1.6
Netherlands	20	22	23	25	25	27	29	30	1.2
Other Western Europe	18	37	38	41	53	62	66	79	3.1
Industrialized Asia	**36**	**57**	**59**	**63**	**66**	**72**	**76**	**85**	**1.5**
Japan	24	41	43	46	48	50	52	54	1.0
Australia/New Zealand	12	15	16	18	18	22	25	31	2.7
Total Industrialized	**505**	**681**	**670**	**730**	**806**	**905**	**1,016**	**1,137**	**2.2**
EE/FSU									
Former Soviet Union	369	301	305	357	400	458	512	566	2.6
Eastern Europe	46	35	38	45	59	74	92	111	4.6
Total EE/FSU	**414**	**336**	**343**	**402**	**459**	**532**	**604**	**677**	**2.9**
Developing Countries									
Developing Asia	**46**	**100**	**114**	**129**	**157**	**217**	**267**	**327**	**4.5**
China	8	16	18	26	40	68	81	110	7.9
India	7	12	12	19	27	37	46	50	6.1
South Korea	2	11	12	15	19	27	34	39	5.0
Other Asia	29	61	73	69	71	86	107	128	2.4
Middle East	**56**	**111**	**119**	**121**	**145**	**164**	**186**	**210**	**2.4**
Turkey	2	8	8	13	19	23	27	31	5.6
Other Middle East	54	103	110	108	127	141	159	179	2.0
Africa	**22**	**32**	**35**	**38**	**44**	**56**	**69**	**82**	**3.6**
Central and South America	**32**	**51**	**55**	**61**	**77**	**101**	**137**	**182**	**5.1**
Brazil	2	5	5	10	19	29	40	52	10.2
Other Central/South America	30	46	50	51	58	72	97	130	4.1
Total Developing	**155**	**294**	**323**	**349**	**424**	**538**	**660**	**800**	**3.9**
Total World	**1,075**	**1,310**	**1,336**	**1,481**	**1,689**	**1,974**	**2,280**	**2,615**	**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 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table A19; and System for the Analysis of Global Energy Markets (2003).

Table A13. World Carbon Dioxide Emissions from Coal Use by Region, Reference Case, 1990-2025
(Million Metric Tons Carbon Equivalent)

Region/Country	History			Projections					Average Annual Percent Change, 2001-2025
	1990	2000	2001	2005	2010	2015	2020	2025	
Industrialized Countries									
North America	**527**	**625**	**610**	**636**	**697**	**733**	**767**	**812**	**1.2**
United States[a]	489	579	561	583	639	673	709	753	1.2
Canada	34	40	42	47	50	49	45	44	0.2
Mexico	4	7	7	7	8	11	13	15	3.3
Western Europe	**316**	**219**	**224**	**215**	**214**	**195**	**176**	**175**	**-1.0**
United Kingdom	68	36	41	37	41	37	34	34	-0.8
France	20	14	12	10	9	5	3	3	-5.3
Germany	137	83	81	81	81	73	62	62	-1.1
Italy	15	13	13	13	14	13	12	12	-0.5
Netherlands	11	13	18	13	17	16	15	15	-0.8
Other Western Europe	66	59	59	61	52	51	49	49	-0.7
Industrialized Asia	**104**	**141**	**147**	**145**	**158**	**166**	**174**	**184**	**0.9**
Japan	66	87	91	87	92	99	102	109	0.7
Australia/New Zealand	37	54	56	58	66	68	71	76	1.3
Total Industrialized	**947**	**985**	**981**	**996**	**1,069**	**1,095**	**1,116**	**1,172**	**0.7**
EE/FSU									
Former Soviet Union	333	187	197	246	226	228	204	185	-0.3
Eastern Europe	189	120	115	98	93	87	78	72	-1.9
Total EE/FSU	**522**	**307**	**312**	**344**	**319**	**314**	**282**	**257**	**-0.8**
Developing Countries									
Developing Asia	**739**	**936**	**993**	**1,040**	**1,244**	**1,425**	**1,637**	**1,864**	**2.7**
China	514	595	639	668	840	980	1,164	1,352	3.2
India	101	161	162	172	194	212	229	261	2.0
South Korea	24	40	42	41	52	58	61	64	1.7
Other Asia	99	139	150	159	159	174	183	187	0.9
Middle East	**20**	**28**	**27**	**33**	**35**	**39**	**42**	**45**	**2.1**
Turkey	16	20	19	21	23	25	27	29	1.7
Other Middle East	4	8	8	12	12	14	15	16	2.8
Africa	**74**	**93**	**95**	**109**	**112**	**122**	**134**	**146**	**1.8**
Central and South America	**15**	**21**	**20**	**23**	**25**	**29**	**29**	**31**	**1.9**
Brazil	9	13	13	14	15	19	19	22	2.1
Other Central/South America	6	8	7	9	10	10	10	9	1.3
Total Developing	**848**	**1,078**	**1,134**	**1,205**	**1,417**	**1,615**	**1,842**	**2,085**	**2.6**
Total World	**2,317**	**2,370**	**2,427**	**2,545**	**2,805**	**3,024**	**3,240**	**3,514**	**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 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table A19; and System for the Analysis of Global Energy Markets (2003).

Table A14. World Total Energy Consumption in Oil-Equivalent Units by Region, Reference Case, 1990-2025
(Million Tons Oil Equivalent)

Region/Country	History 1990	History 2000	History 2001	Projections 2005	Projections 2010	Projections 2015	Projections 2020	Projections 2025	Average Annual Percent Change, 2001-2025
Industrialized Countries									
North America	**2,534**	**2,990**	**2,912**	**3,139**	**3,457**	**3,748**	**4,018**	**4,320**	**1.7**
United States[a]	2,131	2,503	2,446	2,600	2,854	3,072	3,279	3,505	1.5
Canada	278	331	315	359	386	404	416	430	1.3
Mexico	126	156	151	180	217	271	323	385	4.0
Western Europe	**1,509**	**1,685**	**1,718**	**1,741**	**1,816**	**1,881**	**1,947**	**2,028**	**0.7**
United Kingdom	234	246	247	250	262	273	282	293	0.7
France	222	261	265	278	292	305	327	347	1.1
Germany	373	357	362	365	375	386	401	416	0.6
Italy	177	201	204	206	216	227	239	249	0.8
Netherlands	85	99	107	109	113	118	123	128	0.7
Other Western Europe	418	520	533	533	557	572	576	596	0.5
Industrialized Asia	**563**	**692**	**699**	**726**	**776**	**827**	**866**	**916**	**1.1**
Japan	452	548	552	565	599	634	656	683	0.9
Australia/New Zealand	111	144	147	161	177	194	210	233	2.0
Total Industrialized	**4,606**	**5,366**	**5,329**	**5,606**	**6,049**	**6,456**	**6,831**	**7,264**	**1.3**
EE/FSU									
Former Soviet Union	1,529	1,029	1,055	1,239	1,329	1,440	1,528	1,623	1.8
Eastern Europe	393	285	287	299	330	365	405	451	1.9
Total EE/FSU	**1,923**	**1,314**	**1,342**	**1,539**	**1,659**	**1,805**	**1,933**	**2,074**	**1.8**
Developing Countries									
Developing Asia	**1,322**	**2,029**	**2,143**	**2,330**	**2,774**	**3,288**	**3,827**	**4,399**	**3.0**
China	681	931	1,000	1,090	1,371	1,650	1,956	2,288	3.5
India	196	319	322	356	425	506	594	690	3.2
South Korea	95	199	203	226	268	301	327	351	2.3
Other Asia	350	580	617	659	711	831	951	1,070	2.3
Middle East	**329**	**511**	**524**	**538**	**630**	**714**	**806**	**908**	**2.3**
Turkey	50	76	73	91	105	119	134	148	3.0
Other Middle East	280	435	451	448	525	595	672	760	2.2
Africa	**235**	**301**	**314**	**335**	**363**	**405**	**454**	**504**	**2.0**
Central and South America	**364**	**529**	**527**	**571**	**634**	**730**	**842**	**982**	**2.6**
Brazil	150	228	221	236	273	317	364	415	2.7
Other Central/South America	214	302	306	335	361	413	478	567	2.6
Total Developing	**2,250**	**3,371**	**3,508**	**3,775**	**4,401**	**5,137**	**5,929**	**6,793**	**2.8**
Total World	**8,779**	**10,052**	**10,179**	**10,920**	**12,110**	**13,398**	**14,693**	**16,131**	**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 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table A1; and System for the Analysis of Global Energy Markets (2003).

Table A15. World Population by Region, Reference Case, 1990-2025
(Millions)

Region/Country	History 1990	History 2000	History 2001	Projections 2005	Projections 2010	Projections 2015	Projections 2020	Projections 2025	Annual Average Percent Change, 2001-2025
Industrialized Countries									
North America	**366**	**405**	**408**	**426**	**446**	**466**	**486**	**505**	**0.9**
United States[a]	255	276	278	288	300	313	325	338	0.8
Canada	28	31	31	32	33	34	36	37	0.7
Mexico	83	99	99	106	113	119	125	130	1.2
Western Europe	**377**	**389**	**389**	**391**	**391**	**389**	**387**	**384**	**-0.1**
United Kingdom	58	59	59	60	60	61	61	61	0.1
France	57	59	59	60	61	62	62	63	0.2
Germany	79	82	82	82	81	81	80	79	-0.2
Italy	57	58	58	57	56	55	54	52	-0.4
Netherlands	15	16	16	16	16	16	17	17	0.2
Other Western Europe	112	115	115	116	115	115	114	112	-0.1
Industrialized Asia	**144**	**150**	**150**	**152**	**153**	**154**	**153**	**156**	**0.2**
Japan	124	127	127	128	128	128	126	128	0.0
Australia/New Zealand	20	23	23	24	25	26	27	28	0.8
Total Industrialized	**887**	**945**	**947**	**969**	**991**	**1,009**	**1,026**	**1,045**	**0.4**
EE/FSU									
Former Soviet Union	290	291	291	286	283	280	278	274	-0.2
Eastern Europe	122	121	121	120	119	118	116	114	-0.2
Total EE/FSU	**412**	**412**	**412**	**406**	**402**	**398**	**394**	**388**	**-0.2**
Developing Countries									
Developing Asia	**2,788**	**3,237**	**3,237**	**3,447**	**3,652**	**3,846**	**4,026**	**4,186**	**1.1**
China	1,155	1,275	1,275	1,321	1,366	1,410	1,446	1,471	0.6
India	845	1,009	1,009	1,089	1,164	1,230	1,291	1,352	1.2
South Korea	43	47	47	48	50	51	51	52	0.5
Other Asia	745	907	907	989	1,072	1,155	1,237	1,312	1.6
Middle East	**191**	**242**	**242**	**268**	**295**	**325**	**355**	**386**	**2.0**
Turkey	56	67	67	71	75	79	83	87	1.1
Other Middle East	135	175	175	196	220	246	272	299	2.3
Africa	**619**	**794**	**794**	**892**	**997**	**1,110**	**1,231**	**1,358**	**2.3**
Central and South America	**357**	**420**	**420**	**451**	**482**	**511**	**539**	**565**	**1.2**
Brazil	148	170	170	181	191	201	211	219	1.1
Other Central/South America	209	250	250	270	290	310	328	346	1.4
Total Developing	**3,957**	**4,693**	**4,693**	**5,057**	**5,425**	**5,792**	**6,151**	**6,495**	**1.4**
Total World	**5,255**	**6,049**	**6,052**	**6,433**	**6,817**	**7,199**	**7,570**	**7,928**	**1.1**

[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: **United States:** Energy Information Administration, *Annual Energy Outlook 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table A20. **Other Countries:** United Nations, *World Populations: The 2000 Revision, Volume 1, Comprehensive Tables* (New York, NY, 2001).

Appendix B

High Economic Growth Case Projections:

- World Energy Consumption
- Gross Domestic Product
- Carbon Dioxide Emissions

Table B1. World Total 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	2005	2010	2015	2020	2025	
Industrialized Countries									
North America	**100.6**	**118.7**	**115.6**	**126.6**	**142.2**	**156.6**	**171.6**	**187.7**	**2.0**
United States[a]	84.6	99.3	97.0	104.6	116.7	126.9	137.7	149.3	1.8
Canada	11.0	13.2	12.5	14.6	16.2	17.4	18.5	19.1	1.8
Mexico	5.0	6.2	6.0	7.4	9.4	12.2	15.3	19.3	5.0
Western Europe	**59.9**	**66.8**	**68.2**	**70.7**	**76.2**	**81.7**	**87.8**	**94.7**	**1.4**
United Kingdom	9.3	9.8	9.8	9.9	10.6	11.3	11.9	12.5	1.0
France	8.8	10.4	10.5	11.5	12.3	13.1	14.5	15.8	1.7
Germany	14.8	14.2	14.4	14.9	15.5	16.1	17.1	18.0	0.9
Italy	7.0	8.0	8.1	8.5	9.1	9.8	10.5	11.2	1.4
Netherlands	3.4	3.9	4.2	4.4	4.6	4.9	5.2	5.5	1.1
Other Western Europe	16.6	20.6	21.1	21.5	24.0	26.5	28.7	31.7	1.7
Industrialized Asia	**22.3**	**27.5**	**27.7**	**29.6**	**32.7**	**35.8**	**38.8**	**42.3**	**1.8**
Japan	17.9	21.8	21.9	23.0	25.4	27.7	29.7	32.1	1.6
Australia/New Zealand	4.4	5.7	5.8	6.5	7.3	8.2	9.0	10.3	2.4
Total Industrialized	**182.8**	**213.0**	**211.5**	**226.9**	**251.1**	**274.1**	**298.2**	**324.8**	**1.8**
EE/FSU									
Former Soviet Union	60.7	40.8	41.9	53.7	61.3	69.0	76.2	85.3	3.0
Eastern Europe	15.6	11.3	11.4	12.8	15.4	18.7	23.0	28.4	3.9
Total EE/FSU	**76.3**	**52.2**	**53.3**	**66.5**	**76.7**	**87.8**	**99.2**	**113.6**	**3.2**
Developing Countries									
Developing Asia	**52.5**	**80.5**	**85.0**	**95.4**	**118.1**	**145.6**	**176.6**	**209.5**	**3.8**
China	27.0	37.0	39.7	44.6	57.8	72.0	88.6	107.5	4.2
India	7.8	12.7	12.8	14.7	17.9	22.0	26.9	32.4	3.9
South Korea	3.8	7.9	8.1	9.3	11.4	13.5	15.3	17.1	3.2
Other Asia	13.9	23.0	24.5	26.9	31.0	38.2	45.8	52.5	3.2
Middle East	**13.1**	**20.3**	**20.8**	**21.9**	**27.2**	**32.4**	**38.9**	**46.6**	**3.4**
Turkey	2.0	3.0	2.9	3.3	4.0	4.7	5.4	6.2	3.2
Other Middle East	11.1	17.3	17.9	18.5	23.2	27.8	33.5	40.4	3.4
Africa	**9.3**	**11.9**	**12.4**	**13.6**	**15.4**	**17.9**	**20.8**	**23.9**	**2.8**
Central and South America	**14.4**	**21.0**	**20.9**	**22.7**	**26.0**	**30.8**	**36.8**	**44.5**	**3.2**
Brazil	6.0	9.0	8.8	9.6	11.5	13.8	16.4	19.2	3.3
Other Central/South America	8.5	12.0	12.2	13.1	14.5	17.0	20.4	25.3	3.1
Total Developing	**89.3**	**133.8**	**139.2**	**153.6**	**186.7**	**226.8**	**273.0**	**324.5**	**3.6**
Total World	**348.4**	**398.9**	**403.9**	**447.0**	**514.5**	**588.7**	**670.4**	**762.9**	**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 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table B1; and System for the Analysis of Global Energy Markets (2003).

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	2005	2010	2015	2020	2025	
Industrialized Countries									
North America									
Oil	40.4	46.3	45.9	49.4	56.9	63.6	70.0	77.6	2.2
Natural Gas	23.1	28.8	27.6	31.1	35.5	40.0	45.8	51.2	2.6
Coal	20.7	24.5	23.9	25.3	27.9	29.9	31.8	34.0	1.5
Nuclear	6.9	8.7	8.9	9.4	9.6	9.8	9.9	9.7	0.3
Other	9.5	10.6	9.4	11.4	12.3	13.3	14.2	15.3	2.1
Total	**100.6**	**118.7**	**115.6**	**126.6**	**142.2**	**156.6**	**171.6**	**187.7**	**2.0**
Western Europe									
Oil	25.8	28.5	28.9	29.9	31.3	32.9	34.4	36.5	1.0
Natural Gas	9.7	14.9	15.1	16.4	18.9	22.5	27.1	31.7	3.1
Coal	12.4	8.4	8.6	8.6	9.1	8.5	7.9	8.1	-0.2
Nuclear	7.4	8.8	9.1	8.9	9.2	9.4	9.2	8.2	-0.4
Other	4.5	6.0	6.1	6.9	7.6	8.4	9.2	10.1	2.1
Total	**59.9**	**66.8**	**68.2**	**70.7**	**76.2**	**81.7**	**87.8**	**94.7**	**1.4**
Industrialized Asia									
Oil	12.1	13.2	13.0	14.0	15.4	16.9	18.3	20.0	1.8
Natural Gas	2.5	4.0	4.1	4.5	4.9	5.4	6.0	6.6	2.0
Coal	4.2	5.7	5.9	6.0	6.7	7.1	7.5	8.2	1.4
Nuclear	2.0	3.0	3.2	3.2	3.7	4.1	4.4	4.6	1.6
Other	1.6	1.6	1.6	1.9	2.1	2.3	2.5	2.8	2.4
Total	**22.3**	**27.5**	**27.7**	**29.6**	**32.7**	**35.8**	**38.8**	**42.3**	**1.8**
Total Industrialized									
Oil	78.2	88.1	87.8	93.3	103.6	113.4	122.7	134.1	1.8
Natural Gas	35.4	47.7	46.8	51.9	59.3	68.0	78.9	89.5	2.7
Coal	37.3	38.6	38.5	39.9	43.7	45.5	47.2	50.4	1.1
Nuclear	16.3	20.5	21.2	21.5	22.5	23.3	23.5	22.5	0.3
Other	15.6	18.2	17.1	20.2	22.0	24.0	26.0	28.3	2.1
Total	**182.8**	**213.0**	**211.5**	**226.9**	**251.1**	**274.1**	**298.2**	**324.8**	**1.8**
EE/FSU									
Oil	21.0	10.9	11.0	13.9	17.2	21.0	25.3	30.1	4.3
Natural Gas	28.8	23.3	23.8	30.7	37.2	44.0	51.2	59.4	3.9
Coal	20.8	12.2	12.4	15.0	14.9	14.3	13.4	14.1	0.6
Nuclear	2.9	3.0	3.1	3.3	3.5	3.9	3.9	3.8	0.8
Other	2.8	3.0	3.2	3.6	3.9	4.6	5.3	6.2	2.8
Total	**76.3**	**52.2**	**53.3**	**66.5**	**76.7**	**87.8**	**99.2**	**113.6**	**3.2**
Developing Countries									
Developing Asia									
Oil	16.1	30.2	30.7	34.7	42.4	52.2	64.2	77.1	3.9
Natural Gas	3.2	6.9	7.9	9.1	12.0	17.1	21.5	26.4	5.1
Coal	29.1	37.1	39.4	41.4	52.7	62.5	74.8	87.8	3.4
Nuclear	0.9	1.7	1.8	3.4	3.1	4.4	5.0	5.9	5.0
Other	3.2	4.5	5.1	6.8	7.9	9.5	10.9	12.4	3.8
Total	**52.5**	**80.5**	**85.0**	**95.4**	**118.1**	**145.6**	**176.6**	**209.5**	**3.8**

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	2005	2010	2015	2020	2025	
Developing Countries (Continued)									
Middle East									
Oil	8.0	11.0	11.1	11.5	14.2	17.2	20.9	25.4	3.5
Natural Gas	3.9	7.7	8.2	8.4	10.7	12.4	14.6	17.2	3.1
Coal	0.8	1.1	1.1	1.3	1.5	1.8	2.1	2.4	3.3
Nuclear	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.2	—
Other	0.4	0.5	0.4	0.6	0.8	1.0	1.2	1.4	5.3
Total	**13.1**	**20.3**	**20.8**	**21.9**	**27.2**	**32.4**	**38.9**	**46.6**	**3.4**
Africa									
Oil	4.2	5.2	5.3	5.4	6.0	6.9	8.1	9.2	2.3
Natural Gas	1.5	2.2	2.5	2.7	3.3	4.2	5.1	6.3	4.0
Coal	3.0	3.7	3.8	4.4	4.8	5.4	6.1	6.9	2.5
Nuclear	0.1	0.1	0.1	0.2	0.1	0.1	0.2	0.2	1.8
Other	0.6	0.7	0.8	0.9	1.1	1.2	1.3	1.4	2.5
Total	**9.3**	**11.9**	**12.4**	**13.6**	**15.4**	**17.9**	**20.8**	**23.9**	**2.8**
Central and South America									
Oil	7.7	10.6	10.5	11.0	12.5	14.6	16.9	19.8	2.7
Natural Gas	2.2	3.6	3.8	4.2	5.4	7.3	10.1	13.8	5.5
Coal	0.6	0.9	0.8	0.9	1.0	1.1	1.2	1.2	1.9
Nuclear	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3	1.3
Other	3.9	5.9	5.6	6.3	6.9	7.5	8.3	9.3	2.1
Total	**14.4**	**21.0**	**20.9**	**22.7**	**26.0**	**30.8**	**36.8**	**44.5**	**3.2**
Total Developing Countries									
Oil	35.9	56.9	57.6	62.6	75.2	90.9	110.2	131.5	3.5
Natural Gas	10.8	20.4	22.4	24.4	31.2	40.9	51.3	63.7	4.4
Coal	33.5	42.8	45.1	48.1	60.0	70.8	84.2	98.3	3.3
Nuclear	1.1	2.0	2.2	3.8	3.5	5.0	5.6	6.6	4.8
Other	8.0	11.6	11.8	14.7	16.7	19.1	21.7	24.4	3.1
Total	**89.3**	**133.8**	**139.2**	**153.6**	**186.7**	**226.8**	**273.0**	**324.5**	**3.6**
Total World									
Oil	135.1	155.9	156.5	169.8	196.0	225.3	258.1	295.8	2.7
Natural Gas	75.0	91.4	93.1	107.0	127.8	153.0	181.3	212.5	3.5
Coal	91.6	93.6	95.9	103.1	118.7	130.6	144.8	162.8	2.2
Nuclear	20.3	25.5	26.4	28.6	29.5	32.1	33.1	32.9	0.9
Other	26.4	32.8	32.2	38.5	42.6	47.7	53.0	58.9	2.6
Total	**348.4**	**398.9**	**403.9**	**447.0**	**514.5**	**588.7**	**670.4**	**762.9**	**2.7**

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 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table B1; and System for the Analysis of Global Energy Markets (2003).

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	2005	2010	2015	2020	2025	
Industrialized Countries									
North America	**7,723**	**10,555**	**10,588**	**12,541**	**15,632**	**19,239**	**23,346**	**28,286**	**4.2**
United States[a]	6,836	9,370	9,394	11,089	13,766	16,838	20,347	24,558	4.1
Canada	555	731	742	890	1,077	1,286	1,521	1,791	3.7
Mexico	332	453	452	563	788	1,114	1,478	1,936	6.3
Western Europe	**7,597**	**9,312**	**9,460**	**10,896**	**12,888**	**15,186**	**17,886**	**20,909**	**3.4**
United Kingdom	1,146	1,439	1,471	1,701	2,033	2,382	2,771	3,224	3.3
France	1,299	1,564	1,593	1,834	2,175	2,561	3,032	3,547	3.4
Germany	1,879	2,257	2,274	2,604	3,065	3,588	4,192	4,862	3.2
Italy	1,079	1,241	1,263	1,454	1,691	1,995	2,369	2,765	3.3
Netherlands	317	422	427	488	579	683	810	962	3.4
Other Western Europe	1,877	2,389	2,432	2,815	3,346	3,976	4,712	5,549	3.5
Industrialized Asia	**4,054**	**4,922**	**4,920**	**5,546**	**6,496**	**7,539**	**8,695**	**9,993**	**3.0**
Japan	3,673	4,390	4,376	4,893	5,695	6,556	7,494	8,532	2.8
Australia/New Zealand	381	532	545	653	801	983	1,202	1,461	4.2
Total Industrialized	**19,374**	**24,789**	**24,967**	**28,983**	**35,016**	**41,964**	**49,927**	**59,187**	**3.7**
EE/FSU									
Former Soviet Union	1,009	617	654	867	1,212	1,643	2,186	2,900	6.4
Eastern Europe	348	380	390	515	711	984	1,371	1,890	6.8
Total EE/FSU	**1,357**	**997**	**1,044**	**1,382**	**1,923**	**2,628**	**3,557**	**4,790**	**6.6**
Developing Countries									
Developing Asia	**1,739**	**3,393**	**3,525**	**4,648**	**6,435**	**8,672**	**11,491**	**14,888**	**6.2**
China	427	1,119	1,201	1,675	2,405	3,392	4,744	6,427	7.2
India	268	495	521	671	914	1,241	1,679	2,249	6.3
South Korea	297	539	557	742	1,018	1,298	1,586	1,902	5.3
Other Asia	748	1,241	1,247	1,559	2,097	2,742	3,483	4,310	5.3
Middle East	**379**	**590**	**581**	**696**	**890**	**1,121**	**1,399**	**1,729**	**4.7**
Turkey	140	200	185	230	298	382	483	602	5.0
Other Middle East	239	390	395	466	592	740	915	1,127	4.5
Africa	**405**	**596**	**617**	**750**	**949**	**1,186**	**1,473**	**1,813**	**4.6**
Central and South America	**1,136**	**1,497**	**1,505**	**1,699**	**2,184**	**2,826**	**3,685**	**4,843**	**5.0**
Brazil	674	852	865	1,002	1,276	1,641	2,127	2,764	5.0
Other Central/South America	462	645	639	697	909	1,185	1,558	2,079	5.0
Total Developing	**3,660**	**6,077**	**6,228**	**7,793**	**10,458**	**13,806**	**18,048**	**23,273**	**5.6**
Total World	**24,392**	**31,863**	**32,239**	**38,159**	**47,397**	**58,397**	**71,531**	**87,250**	**4.2**

[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 2002), and Energy Information Administration, *Annual Energy Outlook 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), 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	2005	2010	2015	2020	2025	
Industrialized Countries									
North America	**20.4**	**23.8**	**23.5**	**25.4**	**29.2**	**32.8**	**36.0**	**40.0**	**2.2**
United States[a]	17.0	19.7	19.6	20.8	23.9	26.5	28.9	31.8	2.0
Canada	1.7	2.1	1.9	2.2	2.4	2.5	2.7	2.8	1.7
Mexico	1.7	2.0	1.9	2.4	2.9	3.7	4.4	5.3	4.3
Western Europe	**12.5**	**13.8**	**14.0**	**14.5**	**15.1**	**15.9**	**16.6**	**17.7**	**1.0**
United Kingdom	1.8	1.7	1.7	1.8	1.9	2.0	2.1	2.2	1.0
France	1.8	2.0	2.0	2.1	2.2	2.3	2.4	2.5	0.9
Germany	2.7	2.8	2.8	2.9	3.0	3.1	3.2	3.3	0.7
Italy	1.9	1.9	1.9	2.0	2.1	2.2	2.2	2.4	1.0
Netherlands	0.7	0.9	0.9	1.0	1.0	1.0	1.1	1.1	0.9
Other Western Europe	3.6	4.6	4.7	4.8	5.0	5.3	5.7	6.2	1.2
Industrialized Asia	**6.0**	**6.5**	**6.4**	**6.9**	**7.6**	**8.4**	**9.1**	**9.9**	**1.8**
Japan	5.1	5.5	5.4	5.7	6.2	6.8	7.3	7.9	1.6
Australia/New Zealand	0.8	1.0	1.0	1.2	1.4	1.6	1.8	2.1	3.1
Total Industrialized	**38.8**	**44.1**	**43.9**	**46.8**	**52.0**	**57.0**	**61.8**	**67.6**	**1.8**
EE/FSU									
Former Soviet Union	8.4	3.8	3.9	5.0	6.1	7.4	8.8	10.2	4.1
Eastern Europe	1.6	1.4	1.4	1.7	2.1	2.7	3.3	4.3	4.7
Total EE/FSU	**10.0**	**5.2**	**5.3**	**6.7**	**8.3**	**10.1**	**12.1**	**14.5**	**4.3**
Developing Countries									
Developing Asia	**7.6**	**14.5**	**14.8**	**16.7**	**20.4**	**25.1**	**30.9**	**37.1**	**3.9**
China	2.3	4.8	5.0	5.7	7.0	8.5	10.8	12.9	4.0
India	1.2	2.1	2.1	2.3	3.1	4.0	5.3	6.8	5.0
South Korea	1.0	2.1	2.1	2.5	3.0	3.4	3.7	4.1	2.7
Other Asia	3.1	5.5	5.5	6.2	7.4	9.2	11.2	13.3	3.7
Middle East	**3.8**	**5.3**	**5.4**	**5.6**	**6.9**	**8.3**	**10.1**	**12.3**	**3.5**
Turkey	0.5	0.7	0.6	0.7	0.9	1.0	1.2	1.4	3.3
Other Middle East	3.4	4.7	4.7	4.9	6.0	7.3	8.9	11.0	3.6
Africa	**2.1**	**2.5**	**2.6**	**2.6**	**2.9**	**3.4**	**4.0**	**4.5**	**2.3**
Central and South America	**3.7**	**5.2**	**5.2**	**5.4**	**6.2**	**7.2**	**8.3**	**9.7**	**2.7**
Brazil	1.5	2.2	2.2	2.4	2.8	3.3	3.9	4.6	3.1
Other Central/South America	2.3	3.0	3.0	3.0	3.3	3.9	4.4	5.1	2.3
Total Developing	**17.3**	**27.6**	**27.9**	**30.3**	**36.4**	**44.0**	**53.3**	**63.6**	**3.5**
Total World	**66.1**	**76.9**	**77.1**	**83.8**	**96.7**	**111.1**	**127.2**	**145.7**	**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 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table B21; and System for the Analysis of Global Energy Markets (2003).

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 2005	Projections 2010	Projections 2015	Projections 2020	Projections 2025	Average Annual Percent Change, 2001-2025
Industrialized Countries									
North America	**22.5**	**28.1**	**26.9**	**30.3**	**34.5**	**38.9**	**44.5**	**49.7**	**2.6**
United States[a]	19.2	23.5	22.6	25.0	28.1	30.9	34.6	37.5	2.1
Canada	2.4	3.3	2.9	3.4	3.9	4.5	4.9	5.2	2.5
Mexico	0.9	1.4	1.4	1.8	2.5	3.6	5.0	7.0	7.0
Western Europe	**10.1**	**14.6**	**14.8**	**16.0**	**18.5**	**22.0**	**26.5**	**31.0**	**3.1**
United Kingdom	2.1	3.4	3.3	3.5	3.8	4.6	5.0	5.3	2.1
France	1.0	1.4	1.5	1.6	1.7	2.1	2.9	3.7	3.9
Germany	2.7	3.2	3.3	3.5	3.8	4.3	5.7	6.7	3.0
Italy	1.7	2.5	2.5	2.7	2.9	3.3	3.8	4.1	2.1
Netherlands	1.5	1.7	1.8	2.0	2.0	2.1	2.4	2.5	1.5
Other Western Europe	1.2	2.3	2.4	2.8	4.4	5.6	6.7	8.5	5.4
Industrialized Asia	**2.6**	**3.8**	**3.9**	**4.3**	**4.7**	**5.2**	**5.7**	**6.3**	**2.0**
Japan	1.9	2.8	2.8	3.1	3.5	3.7	4.0	4.3	1.8
Australia/New Zealand	0.8	1.0	1.1	1.2	1.2	1.4	1.6	2.0	2.7
Total Industrialized	**35.2**	**46.4**	**45.6**	**50.6**	**57.7**	**66.2**	**76.7**	**87.0**	**2.7**
EE/FSU									
Former Soviet Union	25.0	20.5	20.8	26.8	31.8	36.7	41.4	46.5	3.4
Eastern Europe	3.1	2.4	2.7	3.4	4.9	6.7	9.1	12.1	6.5
Total EE/FSU	**28.1**	**23.0**	**23.5**	**30.2**	**36.7**	**43.4**	**50.5**	**58.6**	**3.9**
Developing Countries									
Developing Asia	**3.0**	**6.6**	**7.5**	**8.7**	**11.4**	**16.2**	**20.4**	**25.0**	**5.1**
China	0.5	1.0	1.0	1.4	2.6	4.3	5.4	7.5	8.8
India	0.4	0.8	0.8	1.3	1.8	2.6	3.1	3.8	6.7
South Korea	0.1	0.7	0.7	0.9	1.3	1.7	2.0	2.3	4.8
Other Asia	2.0	4.2	4.9	5.1	5.6	7.6	9.9	11.4	3.5
Middle East	**3.7**	**7.3**	**7.9**	**8.0**	**10.2**	**11.8**	**13.9**	**16.5**	**3.1**
Turkey	0.1	0.5	0.6	0.7	0.8	1.0	1.2	1.4	3.9
Other Middle East	3.6	6.8	7.3	7.3	9.3	10.8	12.7	15.1	3.1
Africa	1.4	2.0	2.3	2.5	3.0	3.9	4.7	5.8	4.0
Central and South America	**2.0**	**3.3**	**3.5**	**3.9**	**4.9**	**6.7**	**9.3**	**12.7**	**5.5**
Brazil	0.1	0.3	0.3	0.7	1.3	2.1	3.0	4.0	10.8
Other Central/South America	1.9	3.0	3.2	3.2	3.6	4.6	6.3	8.7	4.3
Total Developing	**10.1**	**19.3**	**21.2**	**23.1**	**29.5**	**38.6**	**48.3**	**60.0**	**4.4**
Total World	**73.4**	**88.7**	**90.3**	**103.8**	**123.9**	**148.2**	**175.6**	**205.6**	**3.5**

[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 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table B13; and System for the Analysis of Global Energy Markets (2003).

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	2005	2010	2015	2020	2025	
Industrialized Countries									
North America	**971**	**1,168**	**1,148**	**1,218**	**1,348**	**1,444**	**1,538**	**1,648**	**1.5**
United States[a]	903	1,084	1,060	1,116	1,229	1,319	1,411	1,524	1.5
Canada	59	69	73	87	98	98	93	83	0.6
Mexico	9	15	15	15	21	27	33	41	4.3
Western Europe	**894**	**559**	**574**	**572**	**604**	**565**	**524**	**539**	**-0.3**
United Kingdom	119	64	71	65	65	60	57	57	-0.9
France	35	25	21	17	19	11	8	8	-4.1
Germany	528	264	265	272	275	249	217	221	-0.8
Italy	25	20	22	23	24	22	20	20	-0.3
Netherlands	15	14	23	16	14	13	13	13	-2.6
Other Western Europe	172	172	172	193	227	231	228	240	1.4
Industrialized Asia	**231**	**303**	**312**	**319**	**358**	**377**	**401**	**438**	**1.4**
Japan	125	160	166	163	181	193	206	225	1.3
Australia/New Zealand	106	143	147	155	177	184	195	213	1.6
Total Industrialized	**2,095**	**2,029**	**2,034**	**2,108**	**2,310**	**2,386**	**2,463**	**2,625**	**1.1**
EE/FSU									
Former Soviet Union	848	421	446	619	604	569	525	569	1.0
Eastern Europe	528	390	382	351	363	361	353	349	-0.4
Total EE/FSU	**1,376**	**811**	**828**	**970**	**967**	**930**	**878**	**918**	**0.4**
Developing Countries									
Developing Asia	**1,590**	**1,959**	**2,084**	**2,189**	**2,795**	**3,317**	**3,982**	**4,683**	**3.4**
China	1,124	1,282	1,383	1,463	1,925	2,334	2,876	3,476	3.9
India	242	359	360	360	458	513	590	662	2.6
South Korea	49	72	76	78	102	118	132	143	2.7
Other Asia	175	246	265	288	309	352	384	403	1.8
Middle East	**66**	**94**	**95**	**116**	**135**	**155**	**181**	**207**	**3.3**
Turkey	60	80	81	83	90	101	111	126	1.9
Other Middle East	6	14	14	33	45	54	70	81	7.7
Africa	**152**	**187**	**191**	**222**	**240**	**272**	**307**	**345**	**2.5**
Central and South America	**27**	**34**	**32**	**37**	**40**	**46**	**47**	**50**	**1.9**
Brazil	17	21	21	23	27	34	36	42	3.0
Other Central/South America	10	13	11	14	14	12	11	8	-1.4
Total Developing	**1,835**	**2,275**	**2,401**	**2,563**	**3,210**	**3,790**	**4,516**	**5,284**	**3.3**
Total World	**5,307**	**5,115**	**5,263**	**5,642**	**6,486**	**7,106**	**7,856**	**8,827**	**2.2**

[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 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table B16; and System for the Analysis of Global Energy Markets (2003).

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	2005	2010	2015	2020	2025	
Industrialized Countries									
North America	**649**	**830**	**850**	**894**	**914**	**925**	**937**	**918**	**0.3**
United States[a]	577	754	769	793	800	805	807	807	0.2
Canada	69	69	73	92	104	110	118	98	1.3
Mexico	3	8	8	9	9	10	12	12	1.7
Western Europe	**703**	**845**	**870**	**856**	**883**	**907**	**886**	**791**	**-0.4**
United Kingdom	59	82	86	73	74	49	44	42	-2.9
France	298	394	401	406	434	464	495	505	1.0
Germany	145	161	163	166	148	152	113	53	-4.5
Italy	0	0	0	0	0	0	0	0	—
Netherlands	3	4	4	4	4	4	0	0	-100.0
Other Western Europe	198	204	217	206	224	238	234	191	-0.5
Industrialized Asia	**192**	**294**	**309**	**313**	**358**	**405**	**435**	**451**	**1.6**
Japan	192	294	309	313	358	405	435	451	1.6
Australia/New Zealand	0	0	0	0	0	0	0	0	—
Total Industrialized	**1,544**	**1,969**	**2,029**	**2,063**	**2,155**	**2,238**	**2,258**	**2,160**	**0.3**
EE/FSU									
Former Soviet Union	201	204	210	217	236	256	237	212	0.0
Eastern Europe	54	67	72	80	79	95	119	133	2.6
Total EE/FSU	**256**	**270**	**282**	**297**	**315**	**351**	**356**	**345**	**0.8**
Developing Countries									
Developing Asia	**88**	**171**	**178**	**321**	**306**	**429**	**491**	**572**	**10.4**
China	0	16	17	57	67	137	145	178	10.4
India	6	14	18	88	27	42	49	54	4.6
South Korea	50	104	107	136	148	183	219	271	4.0
Other Asia	32	37	36	40	64	68	77	69	2.8
Middle East	**0**	**0**	**0**	**5**	**5**	**13**	**15**	**24**	**—**
Turkey	0	0	0	0	0	0	0	7	—
Other Middle East	0	0	0	5	5	13	15	17	—
Africa	**8**	**13**	**11**	**16**	**14**	**15**	**16**	**16**	**1.8**
Central and South America	**9**	**11**	**21**	**17**	**18**	**28**	**29**	**31**	**1.6**
Brazil	2	5	14	11	12	21	24	26	2.5
Other Central/South America	7	6	7	6	6	7	5	5	-0.9
Total Developing	**105**	**195**	**209**	**359**	**343**	**486**	**551**	**644**	**4.8**
Total World	**1,905**	**2,434**	**2,521**	**2,719**	**2,814**	**3,074**	**3,165**	**3,149**	**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.

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 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table B8; and System for the Analysis of Global Energy Markets (2003).

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	2005	2010	2015	2020	2025	
Industrialized Countries									
North America	**9.5**	**10.6**	**9.4**	**11.4**	**12.3**	**13.3**	**14.2**	**15.3**	**2.1**
United States[a]	6.0	6.4	5.5	7.1	7.7	8.3	8.8	9.5	2.3
Canada	3.1	3.8	3.5	3.8	4.0	4.4	4.7	5.1	1.6
Mexico	0.3	0.5	0.4	0.5	0.5	0.6	0.7	0.7	2.5
Western Europe	**4.5**	**6.0**	**6.1**	**6.9**	**7.6**	**8.4**	**9.2**	**10.1**	**2.1**
United Kingdom	0.1	0.1	0.1	0.3	0.4	0.5	0.6	0.7	8.7
France	0.6	0.7	0.8	0.7	0.9	1.0	1.1	1.2	1.7
Germany	0.3	0.4	0.5	0.5	0.7	0.8	1.0	1.0	3.2
Italy	0.4	0.6	0.6	1.1	1.2	1.3	1.4	1.5	3.7
Netherlands	0.0	0.1	0.1	0.2	0.2	0.3	0.3	0.4	8.8
Other Western Europe	3.2	4.1	4.1	4.0	4.3	4.6	4.9	5.3	1.1
Industrialized Asia	**1.6**	**1.6**	**1.6**	**1.9**	**2.1**	**2.3**	**2.5**	**2.8**	**2.4**
Japan	1.1	1.1	1.1	1.3	1.4	1.6	1.8	2.0	2.5
Australia/New Zealand	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	2.1
Total Industrialized	**15.6**	**18.2**	**17.1**	**20.2**	**22.0**	**24.0**	**26.0**	**28.3**	**2.1**
EE/FSU									
Former Soviet Union	2.4	2.3	2.5	2.8	2.9	3.4	3.9	4.3	2.3
Eastern Europe	0.4	0.6	0.6	0.8	0.9	1.2	1.5	1.9	4.6
Total EE/FSU	**2.8**	**3.0**	**3.2**	**3.6**	**3.9**	**4.6**	**5.3**	**6.2**	**2.8**
Developing Countries									
Developing Asia	**3.2**	**4.5**	**5.1**	**6.8**	**7.9**	**9.5**	**10.9**	**12.4**	**3.8**
China	1.3	2.3	2.8	3.9	4.6	5.4	6.3	7.2	4.1
India	0.7	0.8	0.8	0.9	1.1	1.3	1.5	1.7	3.1
South Korea	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.2	8.1
Other Asia	1.1	1.4	1.5	1.9	2.2	2.6	2.9	3.3	3.4
Middle East	**0.4**	**0.5**	**0.4**	**0.6**	**0.8**	**1.0**	**1.2**	**1.4**	**5.3**
Turkey	0.2	0.3	0.3	0.4	0.5	0.6	0.7	0.8	4.8
Other Middle East	0.1	0.1	0.1	0.2	0.3	0.4	0.5	0.6	6.0
Africa	**0.6**	**0.7**	**0.8**	**0.9**	**1.1**	**1.2**	**1.3**	**1.4**	**2.5**
Central and South America	**3.9**	**5.9**	**5.6**	**6.3**	**6.9**	**7.5**	**8.3**	**9.3**	**2.1**
Brazil	2.2	3.3	2.9	3.3	3.6	3.9	4.2	4.4	1.7
Other Central/South America	1.7	2.6	2.7	3.1	3.3	3.6	4.2	4.9	2.6
Total Developing	**8.0**	**11.6**	**11.8**	**14.7**	**16.7**	**19.1**	**21.7**	**24.4**	**3.1**
Total World	**26.4**	**32.8**	**32.2**	**38.5**	**42.6**	**47.7**	**53.0**	**58.9**	**2.6**

[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. 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 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table B1; and System for the Analysis of Global Energy Markets (2003).

Table B9. World Net Electricity Consumption by Region, High Economic Growth Case, 1990-2025
(Billion Kilowatthours)

Region/Country	History			Projections					Average Annual Percent Change, 2001-2025
	1990	2000	2001	2005	2010	2015	2020	2025	
Industrialized Countries									
North America	**3,369**	**4,297**	**4,293**	**4,484**	**5,144**	**5,808**	**6,507**	**7,287**	**2.2**
United States[a]	2,827	3,605	3,602	3,720	4,201	4,642	5,095	5,580	1.8
Canada	435	510	504	555	644	737	832	939	2.6
Mexico	107	182	187	208	299	429	580	768	6.1
Western Europe	**2,069**	**2,487**	**2,540**	**2,760**	**3,144**	**3,568**	**4,051**	**4,577**	**2.5**
United Kingdom	286	341	346	359	396	431	466	505	1.6
France	324	406	415	465	513	564	638	718	2.3
Germany	489	502	507	542	585	632	692	756	1.7
Italy	222	282	289	318	359	406	458	513	2.4
Netherlands	71	97	99	118	129	142	156	171	2.3
Other Western Europe	676	858	883	957	1,162	1,394	1,640	1,913	3.3
Industrialized Asia	**930**	**1,165**	**1,183**	**1,254**	**1,420**	**1,588**	**1,779**	**1,967**	**2.1**
Japan	765	944	964	1,017	1,159	1,289	1,434	1,576	2.1
Australia/New Zealand	166	221	219	237	261	299	345	391	2.4
Total Industrialized	**6,368**	**7,950**	**8,016**	**8,498**	**9,709**	**10,964**	**12,337**	**13,831**	**2.3**
EE/FSU									
Former Soviet Union	1,488	1,118	1,135	1,482	1,767	2,075	2,427	2,801	3.8
Eastern Europe	418	385	393	456	586	751	967	1,241	4.9
Total EE/FSU	**1,906**	**1,504**	**1,528**	**1,938**	**2,353**	**2,827**	**3,394**	**4,043**	**4.1**
Developing Countries									
Developing Asia	**1,259**	**2,542**	**2,730**	**3,219**	**4,122**	**5,245**	**6,536**	**7,955**	**4.6**
China	551	1,189	1,312	1,587	2,076	2,680	3,428	4,289	5.1
India	257	477	497	552	699	869	1,058	1,248	3.9
South Korea	93	254	270	309	408	510	603	703	4.1
Other Asia	358	621	650	771	939	1,187	1,447	1,715	4.1
Middle East	**263**	**522**	**543**	**589**	**751**	**941**	**1,166**	**1,433**	**4.1**
Turkey	51	114	113	123	149	176	206	238	3.2
Other Middle East	213	408	430	466	602	765	960	1,195	4.3
Africa	**286**	**388**	**396**	**464**	**568**	**689**	**822**	**963**	**3.8**
Central and South America	**463**	**724**	**721**	**783**	**957**	**1,162**	**1,458**	**1,858**	**4.0**
Brazil	229	359	336	385	470	575	692	825	3.8
Other Central/South America	234	365	385	397	488	588	766	1,033	4.2
Total Developing	**2,272**	**4,175**	**4,390**	**5,055**	**6,399**	**8,038**	**9,983**	**12,209**	**4.4**
Total World	**10,546**	**13,629**	**13,934**	**15,491**	**18,461**	**21,829**	**25,713**	**30,083**	**3.3**

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

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Electricity consumption equals generation plus imports minus exports minus distribution losses.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, *Annual Energy Outlook 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table B2; and System for the Analysis of Global Energy Markets (2003).

Table B10. World Carbon Dioxide Emissions by Region, High Economic Growth Case, 1990-2025
(Million Metric Tons Carbon Equivalent)

Region/Country	History			Projections					Average Annual Percent Change, 2001-2025
	1990	2000	2001	2005	2010	2015	2020	2025	
Industrialized Countries									
North America	**1,564**	**1,836**	**1,810**	**1,943**	**2,205**	**2,436**	**2,677**	**2,944**	**2.0**
United States[a]	1,352	1,578	1,559	1,645	1,852	2,024	2,204	2,401	1.8
Canada	129	158	155	180	202	215	224	230	1.7
Mexico	84	99	96	118	151	198	249	312	5.0
Western Europe	**931**	**939**	**945**	**978**	**1,052**	**1,115**	**1,192**	**1,301**	**1.3**
United Kingdom	164	151	153	155	164	177	185	194	1.0
France	102	109	108	110	115	122	134	153	1.4
Germany	271	226	223	230	238	242	255	276	0.9
Italy	113	121	121	129	136	145	154	164	1.2
Netherlands	58	62	68	67	65	68	72	75	0.4
Other Western Europe	223	270	271	287	332	362	391	440	2.0
Industrialized Asia	**349**	**416**	**424**	**450**	**497**	**540**	**583**	**640**	**1.7**
Japan	269	310	316	330	361	390	418	452	1.5
Australia/New Zealand	80	106	109	120	136	150	166	188	2.3
Total Industrialized	**2,844**	**3,191**	**3,179**	**3,371**	**3,754**	**4,092**	**4,453**	**4,885**	**1.8**
EE/FSU									
Former Soviet Union	1,036	638	654	861	973	1,079	1,182	1,331	3.0
Eastern Europe	301	204	202	214	253	298	354	427	3.2
Total EE/FSU	**1,337**	**842**	**856**	**1,075**	**1,226**	**1,377**	**1,536**	**1,759**	**3.0**
Developing Countries									
Developing Asia	**1,089**	**1,557**	**1,640**	**1,775**	**2,233**	**2,724**	**3,307**	**3,926**	**3.7**
China	617	780	832	901	1,181	1,456	1,804	2,194	4.1
India	153	249	250	265	342	412	500	599	3.7
South Korea	64	116	121	136	169	200	227	252	3.1
Other Asia	256	411	437	474	541	655	776	881	3.0
Middle East	**231**	**344**	**354**	**371**	**461**	**547**	**656**	**787**	**3.4**
Turkey	35	50	50	58	71	82	94	108	3.3
Other Middle East	196	294	304	313	389	465	562	678	3.4
Africa	**179**	**221**	**230**	**250**	**280**	**326**	**379**	**435**	**2.7**
Central and South America	**192**	**262**	**263**	**281**	**326**	**395**	**476**	**584**	**3.4**
Brazil	68	93	95	108	134	167	203	246	4.1
Other Central/South America	124	169	168	172	192	228	273	337	2.9
Total Developing	**1,691**	**2,385**	**2,487**	**2,677**	**3,300**	**3,991**	**4,819**	**5,732**	**3.5**
Total World	**5,872**	**6,417**	**6,522**	**7,124**	**8,280**	**9,460**	**10,807**	**12,376**	**2.7**

[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 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table B19; and System for the Analysis of Global Energy Markets (2003).

Table B11. World Carbon Dioxide Emissions from Oil Use by Region, High Economic Growth Case, 1990-2025
(Million Metric Tons Carbon Equivalent)

Region/Country	History			Projections					Average Annual Percent Change, 2001-2025
	1990	2000	2001	2005	2010	2015	2020	2025	
Industrialized Countries									
North America	**716**	**800**	**807**	**853**	**984**	**1,101**	**1,210**	**1,342**	**2.1**
United States[a]	590	659	668	690	793	877	955	1,050	1.9
Canada	61	70	70	79	87	93	98	105	1.7
Mexico	65	71	68	84	104	131	157	187	4.3
Western Europe	**474**	**505**	**503**	**520**	**545**	**571**	**598**	**636**	**1.0**
United Kingdom	66	63	63	64	69	73	76	80	1.0
France	67	73	73	76	79	83	85	90	0.9
Germany	103	97	95	98	101	105	108	113	0.7
Italy	74	71	71	75	79	83	86	91	1.0
Netherlands	27	27	27	29	29	31	32	33	0.9
Other Western Europe	138	174	174	177	188	197	212	229	1.2
Industrialized Asia	**209**	**219**	**219**	**236**	**260**	**286**	**310**	**340**	**1.9**
Japan	179	182	182	193	210	228	244	264	1.6
Australia/New Zealand	31	37	37	43	50	58	66	76	3.1
Total Industrialized	**1,400**	**1,524**	**1,528**	**1,609**	**1,788**	**1,958**	**2,119**	**2,318**	**1.7**
EE/FSU									
Former Soviet Union	334	149	152	194	240	290	343	399	4.1
Eastern Europe	66	49	49	60	75	93	117	149	4.7
Total EE/FSU	**400**	**199**	**201**	**254**	**314**	**383**	**461**	**548**	**4.3**
Developing Countries									
Developing Asia	**304**	**522**	**533**	**601**	**734**	**904**	**1,113**	**1,336**	**3.9**
China	94	169	175	200	245	301	379	454	4.0
India	45	76	76	84	109	143	189	245	5.0
South Korea	38	65	67	77	93	105	116	127	2.7
Other Asia	128	211	215	240	287	355	429	510	3.7
Middle East	**155**	**205**	**208**	**217**	**268**	**324**	**394**	**479**	**3.5**
Turkey	17	22	22	25	32	37	43	48	3.3
Other Middle East	137	183	186	192	236	287	351	430	3.6
Africa	**83**	**97**	**100**	**101**	**114**	**130**	**153**	**173**	**2.3**
Central and South America	**145**	**189**	**188**	**197**	**224**	**262**	**302**	**354**	**2.7**
Brazil	57	75	76	84	98	114	136	160	3.1
Other Central/South America	88	114	112	112	126	147	166	194	2.3
Total Developing	**688**	**1,013**	**1,029**	**1,116**	**1,340**	**1,619**	**1,962**	**2,342**	**3.5**
Total World	**2,488**	**2,736**	**2,759**	**2,979**	**3,443**	**3,960**	**4,542**	**5,208**	**2.7**

[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 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table B19; and System for the Analysis of Global Energy Markets (2003).

Table B12. World Carbon Dioxide Emissions from Natural Gas Use by Region, High Economic Growth Case, 1990-2025
(Million Metric Tons Carbon Equivalent)

Region/Country	History			Projections					Average Annual Percent Change, 2001-2025
	1990	2000	2001	2005	2010	2015	2020	2025	
Industrialized Countries									
North America	**329**	**410**	**393**	**445**	**508**	**573**	**656**	**733**	**2.6**
United States[a]	280	341	329	367	413	453	507	550	2.2
Canada	35	48	43	50	58	65	72	77	2.5
Mexico	15	21	21	28	38	55	76	107	7.0
Western Europe	**140**	**214**	**218**	**236**	**273**	**324**	**390**	**456**	**3.1**
United Kingdom	30	51	50	54	58	70	77	81	2.1
France	16	22	23	24	26	32	45	58	3.0
Germany	32	45	47	49	53	61	80	95	3.0
Italy	25	37	37	40	43	49	56	61	2.1
Netherlands	20	22	23	25	26	27	30	32	1.5
Other Western Europe	18	37	38	44	67	85	102	128	5.2
Industrialized Asia	**36**	**57**	**59**	**65**	**71**	**78**	**86**	**96**	**2.0**
Japan	24	41	43	47	52	56	61	65	1.8
Australia/New Zealand	12	15	16	18	18	22	25	31	2.7
Total Industrialized	**505**	**681**	**670**	**746**	**851**	**976**	**1,132**	**1,285**	**2.8**
EE/FSU									
Former Soviet Union	369	301	305	393	466	538	607	681	3.4
Eastern Europe	46	35	38	49	70	96	131	173	6.5
Total EE/FSU	**414**	**336**	**343**	**442**	**536**	**634**	**737**	**855**	**3.9**
Developing Countries									
Developing Asia	**46**	**100**	**114**	**131**	**172**	**246**	**310**	**380**	**5.1**
China	8	16	18	26	46	77	97	134	8.8
India	7	12	12	19	27	39	46	57	6.7
South Korea	2	11	12	15	20	30	38	46	5.8
Other Asia	29	61	73	71	79	100	129	143	2.9
Middle East	**56**	**111**	**119**	**121**	**153**	**178**	**210**	**248**	**3.1**
Turkey	2	8	8	13	18	20	25	30	5.4
Other Middle East	54	103	110	108	136	158	185	218	2.9
Africa	**22**	**32**	**35**	**39**	**47**	**61**	**73**	**91**	**4.0**
Central and South America	**32**	**51**	**55**	**61**	**77**	**105**	**145**	**199**	**5.5**
Brazil	2	5	5	10	20	31	45	60	10.8
Other Central/South America	30	46	50	51	58	73	100	139	4.4
Total Developing	**155**	**294**	**323**	**351**	**449**	**589**	**738**	**917**	**4.4**
Total World	**1,075**	**1,310**	**1,336**	**1,538**	**1,837**	**2,199**	**2,607**	**3,056**	**3.5**

[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 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table B19; and System for the Analysis of Global Energy Markets (2003).

Table B13. World Carbon Dioxide Emissions from Coal Use by Region, High Economic Growth Case, 1990-2025
(Million Metric Tons Carbon Equivalent)

Region/Country	History			Projections					Average Annual Percent Change, 2001-2025
	1990	2000	2001	2005	2010	2015	2020	2025	
Industrialized Countries									
North America	**527**	**625**	**610**	**645**	**713**	**762**	**811**	**869**	**1.5**
United States[a]	489	579	561	588	646	693	742	802	1.5
Canada	34	40	42	50	57	57	54	48	0.6
Mexico	4	7	7	7	9	12	15	19	4.3
Western Europe	**316**	**219**	**224**	**223**	**234**	**219**	**203**	**209**	**-0.3**
United Kingdom	68	36	41	37	37	35	32	33	-0.9
France	20	14	12	10	11	6	4	4	-4.1
Germany	137	83	81	83	84	76	67	68	-0.8
Italy	15	13	13	14	14	13	12	12	-0.3
Netherlands	11	13	18	13	11	10	10	10	-2.6
Other Western Europe	66	59	59	66	77	79	78	82	1.4
Industrialized Asia	**104**	**141**	**147**	**149**	**167**	**176**	**188**	**205**	**1.4**
Japan	66	87	91	90	99	106	113	124	1.3
Australia/New Zealand	37	54	56	59	68	70	74	81	1.6
Total Industrialized	**947**	**985**	**981**	**1,017**	**1,114**	**1,158**	**1,202**	**1,283**	**1.1**
EE/FSU									
Former Soviet Union	333	187	197	274	267	251	232	251	1.0
Eastern Europe	189	120	115	105	109	108	106	105	-0.4
Total EE/FSU	**522**	**307**	**312**	**379**	**376**	**360**	**338**	**356**	**0.6**
Developing Countries									
Developing Asia	**739**	**936**	**993**	**1,044**	**1,327**	**1,573**	**1,885**	**2,211**	**3.4**
China	514	595	639	676	889	1,078	1,328	1,605	3.9
India	101	161	162	162	206	231	265	298	2.6
South Korea	24	40	42	44	57	66	73	79	2.7
Other Asia	99	139	150	163	175	199	218	229	1.8
Middle East	**20**	**28**	**27**	**33**	**39**	**45**	**52**	**60**	**3.3**
Turkey	16	20	19	20	21	24	27	30	1.9
Other Middle East	4	8	8	14	18	21	26	30	5.6
Africa	**74**	**93**	**95**	**110**	**119**	**135**	**152**	**171**	**2.5**
Central and South America	**15**	**21**	**20**	**23**	**25**	**29**	**29**	**31**	**1.9**
Brazil	9	13	13	14	17	21	22	26	3.0
Other Central/South America	6	8	7	9	9	7	7	5	-1.4
Total Developing	**848**	**1,078**	**1,134**	**1,210**	**1,510**	**1,782**	**2,119**	**2,473**	**3.3**
Total World	**2,317**	**2,370**	**2,427**	**2,606**	**3,000**	**3,300**	**3,658**	**4,112**	**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 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table B19; and System for the Analysis of Global Energy Markets (2003).

Table B14. 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	2005	2010	2015	2020	2025	
Industrialized Countries									
North America	**2,534**	**2,990**	**2,912**	**3,190**	**3,584**	**3,946**	**4,324**	**4,731**	**2.0**
United States[a]	2,131	2,503	2,446	2,635	2,941	3,198	3,470	3,761	1.8
Canada	278	331	315	368	408	439	467	482	1.8
Mexico	126	156	151	187	236	308	387	487	5.0
Western Europe	**1,509**	**1,685**	**1,718**	**1,782**	**1,921**	**2,060**	**2,213**	**2,386**	**1.4**
United Kingdom	234	246	247	251	268	284	299	315	1.0
France	222	261	265	290	311	331	364	398	1.7
Germany	373	357	362	374	390	407	430	453	0.9
Italy	177	201	204	215	230	248	265	282	1.4
Netherlands	85	99	107	111	117	123	130	138	1.1
Other Western Europe	418	520	533	541	604	667	724	800	1.7
Industrialized Asia	**563**	**692**	**699**	**745**	**824**	**903**	**977**	**1,067**	**1.8**
Japan	452	548	552	581	640	698	749	808	1.6
Australia/New Zealand	111	144	147	164	184	206	228	259	2.4
Total Industrialized	**4,606**	**5,366**	**5,329**	**5,717**	**6,329**	**6,908**	**7,514**	**8,184**	**1.8**
EE/FSU									
Former Soviet Union	1,529	1,029	1,055	1,354	1,546	1,740	1,919	2,149	3.0
Eastern Europe	393	285	287	323	387	472	579	715	3.9
Total EE/FSU	**1,923**	**1,314**	**1,342**	**1,676**	**1,933**	**2,211**	**2,499**	**2,864**	**3.2**
Developing Countries									
Developing Asia	**1,322**	**2,029**	**2,143**	**2,404**	**2,976**	**3,670**	**4,450**	**5,280**	**3.8**
China	681	931	1,000	1,123	1,455	1,814	2,233	2,708	4.2
India	196	319	322	370	451	555	677	816	3.9
South Korea	95	199	203	234	288	340	385	432	3.2
Other Asia	350	580	617	678	781	962	1,154	1,324	3.2
Middle East	**329**	**511**	**524**	**552**	**687**	**817**	**980**	**1,174**	**3.4**
Turkey	50	76	73	84	101	118	137	156	3.2
Other Middle East	280	435	451	467	585	699	843	1,018	3.4
Africa	**235**	**301**	**314**	**343**	**387**	**452**	**524**	**603**	**2.8**
Central and South America	**364**	**529**	**527**	**572**	**654**	**777**	**927**	**1,120**	**3.2**
Brazil	150	228	221	241	289	348	412	483	3.3
Other Central/South America	214	302	306	331	365	429	515	637	3.1
Total Developing	**2,250**	**3,371**	**3,508**	**3,870**	**4,704**	**5,716**	**6,881**	**8,178**	**3.6**
Total World	**8,779**	**10,052**	**10,179**	**11,263**	**12,966**	**14,836**	**16,894**	**19,226**	**2.7**

[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 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table B1; and System for the Analysis of Global Energy Markets (2003).

Appendix C

Low Economic Growth Case Projections:

- World Energy Consumption
- Gross Domestic Product
- Carbon Dioxide Emissions

Table C1. World Total Energy Consumption by Region, Low Economic Growth Case, 1990-2025
(Quadrillion Btu)

Region/Country	History			Projections					Average Annual Percent Change, 2001-2025
	1990	2000	2001	2005	2010	2015	2020	2025	
Industrialized Countries									
North America	**100.6**	**118.7**	**115.6**	**122.7**	**133.2**	**142.1**	**149.7**	**157.2**	**1.3**
United States[a]	84.6	99.3	97.0	101.9	110.7	117.7	123.7	129.4	1.2
Canada	11.0	13.2	12.5	13.9	14.5	15.0	15.4	15.7	1.0
Mexico	5.0	6.2	6.0	6.9	8.0	9.4	10.6	12.1	3.0
Western Europe	**59.9**	**66.8**	**68.2**	**67.6**	**68.5**	**69.2**	**69.6**	**69.7**	**0.1**
United Kingdom	9.3	9.8	9.8	9.7	9.9	10.0	10.0	10.1	0.1
France	8.8	10.4	10.5	10.4	10.6	10.7	10.8	10.9	0.2
Germany	14.8	14.2	14.4	14.2	14.3	14.5	14.5	14.6	0.1
Italy	7.0	8.0	8.1	8.0	8.1	8.3	8.3	8.4	0.1
Netherlands	3.4	3.9	4.2	4.2	4.2	4.3	4.3	4.3	0.1
Other Western Europe	16.6	20.6	21.1	20.9	21.3	21.5	21.5	21.5	0.1
Industrialized Asia	**22.3**	**27.5**	**27.7**	**28.2**	**29.2**	**30.2**	**30.9**	**31.8**	**0.6**
Japan	17.9	21.8	21.9	21.9	22.4	22.8	23.0	23.3	0.3
Australia/New Zealand	4.4	5.7	5.8	6.3	6.8	7.4	7.9	8.4	1.6
Total Industrialized	**182.8**	**213.0**	**211.5**	**218.5**	**230.9**	**241.5**	**250.2**	**258.7**	**0.8**
EE/FSU									
Former Soviet Union	60.7	40.8	41.9	47.5	50.8	53.4	55.2	57.1	1.3
Eastern Europe	15.6	11.3	11.4	11.5	12.3	13.2	14.1	15.1	1.2
Total EE/FSU	**76.3**	**52.2**	**53.3**	**59.1**	**63.1**	**66.6**	**69.3**	**72.2**	**1.3**
Developing Countries									
Developing Asia	**52.5**	**80.5**	**85.0**	**87.7**	**96.9**	**108.2**	**118.8**	**129.1**	**1.8**
China	27.0	37.0	39.7	39.9	45.5	50.5	55.7	60.3	1.8
India	7.8	12.7	12.8	13.7	15.9	18.4	20.9	23.5	2.6
South Korea	3.8	7.9	8.1	8.7	9.9	10.7	11.1	11.4	1.5
Other Asia	13.9	23.0	24.5	25.4	25.6	28.5	31.1	33.9	1.4
Middle East	**13.1**	**20.3**	**20.8**	**20.5**	**23.2**	**24.7**	**27.2**	**29.8**	**1.5**
Turkey	2.0	3.0	2.9	3.0	3.4	3.7	4.1	4.4	1.8
Other Middle East	11.1	17.3	17.9	17.5	19.8	20.9	23.1	25.4	1.5
Africa	**9.3**	**11.9**	**12.4**	**13.0**	**13.4**	**14.6**	**15.8**	**17.1**	**1.3**
Central and South America	**14.4**	**21.0**	**20.9**	**21.8**	**24.4**	**26.7**	**30.3**	**34.7**	**2.1**
Brazil	6.0	9.0	8.8	8.9	10.0	11.2	12.4	13.7	1.9
Other Central/South America	8.5	12.0	12.2	12.9	14.4	15.5	17.9	21.0	2.3
Total Developing	**89.3**	**133.8**	**139.2**	**143.0**	**157.9**	**174.1**	**192.1**	**210.7**	**1.7**
Total World	**348.4**	**398.9**	**403.9**	**420.6**	**451.9**	**482.2**	**511.5**	**541.7**	**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 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table B1; and System for the Analysis of Global Energy Markets (2003).

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	2005	2010	2015	2020	2025	
Industrialized Countries									
North America									
Oil	40.4	46.3	45.9	47.2	52.0	56.2	59.2	62.4	1.3
Natural Gas	23.1	28.8	27.6	30.2	33.0	36.1	39.2	42.2	1.8
Coal	20.7	24.5	23.9	24.7	26.7	27.7	28.7	30.0	0.9
Nuclear	6.9	8.7	8.9	9.4	9.6	9.7	9.7	9.4	0.2
Other	9.5	10.6	9.4	11.2	11.9	12.5	12.9	13.2	1.4
Total	**100.6**	**118.7**	**115.6**	**122.7**	**133.2**	**142.1**	**149.7**	**157.2**	**1.3**
Western Europe									
Oil	25.8	28.5	28.9	28.5	28.2	28.0	27.5	27.6	-0.2
Natural Gas	9.7	14.9	15.1	15.4	16.5	18.2	20.1	21.6	1.5
Coal	12.4	8.4	8.6	8.0	7.7	6.7	5.7	5.5	-1.9
Nuclear	7.4	8.8	9.1	8.9	9.1	8.6	7.8	6.6	-1.4
Other	4.5	6.0	6.1	6.8	7.1	7.8	8.4	8.5	1.4
Total	**59.9**	**66.8**	**68.2**	**67.6**	**68.5**	**69.2**	**69.6**	**69.7**	**0.1**
Industrialized Asia									
Oil	12.1	13.2	13.0	12.9	13.2	13.5	13.7	13.9	0.3
Natural Gas	2.5	4.0	4.1	4.4	4.2	4.5	4.7	5.1	0.9
Coal	4.2	5.7	5.9	5.8	6.2	6.3	6.5	6.7	0.5
Nuclear	2.0	3.0	3.2	3.2	3.6	3.8	3.8	3.8	0.7
Other	1.6	1.6	1.6	1.9	2.0	2.1	2.1	2.3	1.4
Total	**22.3**	**27.5**	**27.7**	**28.2**	**29.2**	**30.2**	**30.9**	**31.8**	**0.6**
Total Industrialized									
Oil	78.2	88.1	87.8	88.6	93.4	97.6	100.4	103.9	0.7
Natural Gas	35.4	47.7	46.8	50.0	53.7	58.8	64.1	68.9	1.6
Coal	37.3	38.6	38.5	38.5	40.5	40.7	40.9	42.2	0.4
Nuclear	16.3	20.5	21.2	21.5	22.3	22.1	21.4	19.8	-0.3
Other	15.6	18.2	17.1	19.9	21.0	22.3	23.4	24.0	1.4
Total	**182.8**	**213.0**	**211.5**	**218.5**	**230.9**	**241.5**	**250.2**	**258.7**	**0.8**
EE/FSU									
Oil	21.0	10.9	11.0	12.1	13.1	13.5	14.1	15.1	1.3
Natural Gas	28.8	23.3	23.8	27.0	30.8	34.6	38.5	41.8	2.4
Coal	20.8	12.2	12.4	13.2	12.1	11.5	10.0	8.9	-1.4
Nuclear	2.9	3.0	3.1	3.3	3.3	3.3	2.9	2.5	-0.9
Other	2.8	3.0	3.2	3.5	3.7	3.8	3.8	3.9	0.9
Total	**76.3**	**52.2**	**53.3**	**59.1**	**63.1**	**66.6**	**69.3**	**72.2**	**1.3**
Developing Countries									
Developing Asia									
Oil	16.1	30.2	30.7	31.8	34.8	38.6	42.7	46.2	1.7
Natural Gas	3.2	6.9	7.9	8.8	9.6	12.2	16.0	18.3	3.5
Coal	29.1	37.1	39.4	39.0	41.6	44.8	46.4	50.1	1.0
Nuclear	0.9	1.7	1.8	2.6	3.1	4.0	4.3	4.6	4.0
Other	3.2	4.5	5.1	5.6	7.8	8.6	9.4	10.0	2.9
Total	**52.5**	**80.5**	**85.0**	**87.7**	**96.9**	**108.2**	**118.8**	**129.1**	**1.8**

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			Projections					Average Annual Percent Change, 2001-2025
	1990	2000	2001	2005	2010	2015	2020	2025	
Developing Countries (Continued)									
Middle East									
Oil	8.0	11.0	11.1	10.5	11.3	12.2	13.0	13.8	0.9
Natural Gas	3.9	7.7	8.2	8.3	9.8	10.2	11.8	13.4	2.0
Coal	0.8	1.1	1.1	1.3	1.3	1.3	1.4	1.4	1.0
Nuclear	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	—
Other	0.4	0.5	0.4	0.4	0.7	0.9	1.0	1.1	4.1
Total	**13.1**	**20.3**	**20.8**	**20.5**	**23.2**	**24.7**	**27.2**	**29.8**	**1.5**
Africa									
Oil	4.2	5.2	5.3	4.9	5.1	5.1	5.3	5.6	0.2
Natural Gas	1.5	2.2	2.5	2.6	2.9	3.7	4.4	5.1	3.1
Coal	3.0	3.7	3.8	4.3	4.2	4.5	4.8	5.0	1.2
Nuclear	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.9
Other	0.6	0.7	0.8	0.9	1.1	1.1	1.2	1.2	1.7
Total	**9.3**	**11.9**	**12.4**	**13.0**	**13.4**	**14.6**	**15.8**	**17.1**	**1.3**
Central and South America									
Oil	7.7	10.6	10.5	10.5	11.4	12.4	13.6	15.3	1.6
Natural Gas	2.2	3.6	3.8	4.2	5.3	6.5	8.6	11.2	4.6
Coal	0.6	0.9	0.8	0.9	1.0	1.1	1.2	1.2	1.9
Nuclear	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.4
Other	3.9	5.9	5.6	5.9	6.5	6.5	6.7	6.8	0.8
Total	**14.4**	**21.0**	**20.9**	**21.8**	**24.4**	**26.7**	**30.3**	**34.7**	**2.1**
Total Developing Countries									
Oil	35.9	56.9	57.6	57.8	62.6	68.2	74.6	80.9	1.4
Natural Gas	10.8	20.4	22.4	23.9	27.7	32.6	40.8	47.9	3.2
Coal	33.5	42.8	45.1	45.6	48.1	51.7	53.7	57.7	1.0
Nuclear	1.1	2.0	2.2	3.0	3.4	4.4	4.8	5.2	3.7
Other	8.0	11.6	11.8	12.8	16.1	17.2	18.2	19.1	2.0
Total	**89.3**	**133.8**	**139.2**	**143.0**	**157.9**	**174.1**	**192.1**	**210.7**	**1.7**
Total World									
Oil	135.1	155.9	156.5	158.5	169.2	179.3	189.1	199.9	1.0
Natural Gas	75.0	91.4	93.1	100.9	112.3	125.9	143.3	158.5	2.2
Coal	91.6	93.6	95.9	97.2	100.6	103.9	104.5	108.8	0.5
Nuclear	20.3	25.5	26.4	27.8	29.1	29.8	29.1	27.5	0.2
Other	26.4	32.8	32.2	36.2	40.7	43.3	45.4	47.0	1.6
Total	**348.4**	**398.9**	**403.9**	**420.6**	**451.9**	**482.2**	**511.5**	**541.7**	**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 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table B1; and System for the Analysis of Global Energy Markets (2003).

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	2005	2010	2015	2020	2025	
Industrialized Countries									
North America	**7,723**	**10,555**	**10,588**	**11,376**	**12,873**	**14,381**	**15,836**	**17,411**	**2.1**
United States[a]	6,836	9,370	9,394	10,057	11,335	12,583	13,796	15,108	2.0
Canada	555	731	742	807	887	961	1,030	1,100	1.7
Mexico	332	453	452	511	651	838	1,010	1,203	4.2
Western Europe	**7,597**	**9,312**	**9,460**	**9,880**	**10,600**	**11,327**	**12,098**	**12,824**	**1.3**
United Kingdom	1,146	1,439	1,471	1,543	1,673	1,777	1,874	1,977	1.2
France	1,299	1,564	1,593	1,663	1,789	1,910	2,052	2,176	1.3
Germany	1,879	2,257	2,274	2,361	2,519	2,675	2,833	2,980	1.1
Italy	1,079	1,241	1,263	1,318	1,390	1,488	1,603	1,695	1.2
Netherlands	317	422	427	443	476	510	548	590	1.4
Other Western Europe	1,877	2,389	2,432	2,553	2,752	2,967	3,189	3,406	1.4
Industrialized Asia	**4,054**	**4,922**	**4,920**	**5,025**	**5,338**	**5,616**	**5,872**	**6,118**	**0.9**
Japan	3,673	4,390	4,376	4,433	4,678	4,882	5,057	5,218	0.7
Australia/New Zealand	381	532	545	592	660	735	815	900	2.1
Total Industrialized	**19,374**	**24,789**	**24,967**	**26,281**	**28,810**	**31,325**	**33,807**	**36,354**	**1.6**
EE/FSU									
Former Soviet Union	1,009	617	654	734	869	997	1,121	1,257	2.8
Eastern Europe	348	380	390	436	509	597	703	821	3.2
Total EE/FSU	**1,357**	**997**	**1,044**	**1,170**	**1,378**	**1,593**	**1,824**	**2,077**	**2.9**
Developing Countries									
Developing Asia	**1,739**	**3,393**	**3,525**	**4,123**	**5,060**	**6,032**	**7,050**	**8,045**	**3.5**
China	427	1,119	1,201	1,422	1,730	2,066	2,447	2,804	3.6
India	268	495	521	610	756	934	1,148	1,399	4.2
South Korea	297	539	557	675	843	975	1,081	1,177	3.2
Other Asia	748	1,241	1,247	1,416	1,731	2,057	2,373	2,666	3.2
Middle East	**379**	**590**	**581**	**631**	**733**	**839**	**950**	**1,066**	**2.6**
Turkey	140	200	185	209	246	285	328	372	2.9
Other Middle East	239	390	395	422	488	553	621	694	2.4
Africa	**405**	**596**	**617**	**681**	**782**	**888**	**1,001**	**1,119**	**2.5**
Central and South America	**1,136**	**1,497**	**1,505**	**1,540**	**1,798**	**2,114**	**2,504**	**2,992**	**2.9**
Brazil	674	852	865	909	1,051	1,228	1,446	1,708	2.9
Other Central/South America	462	645	639	631	748	886	1,058	1,284	2.9
Total Developing	**3,660**	**6,077**	**6,228**	**6,975**	**8,374**	**9,873**	**11,506**	**13,222**	**3.2**
Total World	**24,392**	**31,863**	**32,239**	**34,426**	**38,562**	**42,790**	**47,137**	**51,652**	**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.

Sources: Global Insight, Inc., *World Economic Outlook*, Vol. 1 (Lexington, MA, Third Quarter 2002), and Energy Information Administration, *Annual Energy Outlook 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), 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	2005	2010	2015	2020	2025	
Industrialized Countries									
North America	**20.4**	**23.8**	**23.5**	**24.3**	**26.7**	**28.9**	**30.5**	**32.1**	**1.3**
United States[a]	17.0	19.7	19.6	20.1	22.3	24.1	25.5	26.9	1.3
Canada	1.7	2.1	1.9	2.0	2.0	2.0	2.0	2.1	0.3
Mexico	1.7	2.0	1.9	2.1	2.4	2.8	2.9	3.2	2.0
Western Europe	**12.5**	**13.8**	**14.0**	**13.8**	**13.7**	**13.5**	**13.3**	**13.3**	**-0.2**
United Kingdom	1.8	1.7	1.7	1.7	1.7	1.8	1.8	1.8	0.1
France	1.8	2.0	2.0	2.0	2.0	1.9	1.9	1.8	-0.5
Germany	2.7	2.8	2.8	2.8	2.8	2.8	2.8	2.7	-0.1
Italy	1.9	1.9	1.9	1.8	1.9	1.9	1.8	1.8	-0.2
Netherlands	0.7	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.0
Other Western Europe	3.6	4.6	4.7	4.5	4.3	4.3	4.1	4.4	-0.3
Industrialized Asia	**6.0**	**6.5**	**6.4**	**6.4**	**6.6**	**6.7**	**6.8**	**6.9**	**0.3**
Japan	5.1	5.5	5.4	5.3	5.4	5.4	5.4	5.4	0.0
Australia/New Zealand	0.8	1.0	1.0	1.1	1.2	1.3	1.4	1.5	1.6
Total Industrialized	**38.8**	**44.1**	**43.9**	**44.5**	**46.9**	**49.1**	**50.6**	**52.4**	**0.7**
EE/FSU									
Former Soviet Union	8.4	3.8	3.9	4.3	4.7	4.7	4.9	5.2	1.2
Eastern Europe	1.6	1.4	1.4	1.5	1.6	1.7	1.9	2.1	1.6
Total EE/FSU	**10.0**	**5.2**	**5.3**	**5.8**	**6.3**	**6.5**	**6.8**	**7.3**	**1.3**
Developing Countries									
Developing Asia	**7.6**	**14.5**	**14.8**	**15.3**	**16.7**	**18.6**	**20.6**	**22.2**	**1.7**
China	2.3	4.8	5.0	5.1	5.7	6.2	7.0	7.4	1.7
India	1.2	2.1	2.1	2.2	2.6	3.1	3.7	4.3	3.0
South Korea	1.0	2.1	2.1	2.3	2.5	2.7	2.7	2.7	1.0
Other Asia	3.1	5.5	5.5	5.7	6.0	6.6	7.2	7.8	1.4
Middle East	**3.8**	**5.3**	**5.4**	**5.1**	**5.5**	**5.9**	**6.3**	**6.7**	**0.9**
Turkey	0.5	0.7	0.6	0.7	0.7	0.8	0.9	1.0	1.9
Other Middle East	3.4	4.7	4.7	4.5	4.8	5.1	5.4	5.7	0.8
Africa	**2.1**	**2.5**	**2.6**	**2.4**	**2.5**	**2.5**	**2.6**	**2.7**	**0.2**
Central and South America	**3.7**	**5.2**	**5.2**	**5.2**	**5.6**	**6.1**	**6.7**	**7.5**	**1.6**
Brazil	1.5	2.2	2.2	2.2	2.5	2.8	3.0	3.3	1.7
Other Central/South America	2.3	3.0	3.0	2.9	3.1	3.3	3.7	4.2	1.4
Total Developing	**17.3**	**27.6**	**27.9**	**28.0**	**30.3**	**33.0**	**36.1**	**39.2**	**1.4**
Total World	**66.1**	**76.9**	**77.1**	**78.2**	**83.5**	**88.6**	**93.5**	**98.8**	**1.0**

[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 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table B21; and System for the Analysis of Global Energy Markets (2003).

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	2005	2010	2015	2020	2025	
Industrialized Countries									
North America	**22.5**	**28.1**	**26.9**	**29.4**	**32.2**	**35.1**	**38.2**	**41.1**	**1.8**
United States[a]	19.2	23.5	22.6	24.3	26.3	28.4	30.3	31.8	1.4
Canada	2.4	3.3	2.9	3.3	3.6	3.9	4.2	4.7	2.0
Mexico	0.9	1.4	1.4	1.8	2.3	2.8	3.6	4.6	5.2
Western Europe	**10.1**	**14.6**	**14.8**	**15.0**	**16.1**	**17.8**	**19.7**	**21.1**	**1.5**
United Kingdom	2.1	3.4	3.3	3.3	3.5	3.6	4.1	4.3	1.1
France	1.0	1.4	1.5	1.5	1.4	1.4	1.7	2.2	1.6
Germany	2.7	3.2	3.3	3.3	3.3	3.5	3.9	4.9	1.6
Italy	1.7	2.5	2.5	2.5	2.6	2.6	2.8	3.0	0.8
Netherlands	1.5	1.7	1.8	1.7	1.9	1.8	1.9	2.0	0.5
Other Western Europe	1.2	2.3	2.4	2.8	3.4	4.8	5.3	4.8	2.9
Industrialized Asia	**2.6**	**3.8**	**3.9**	**4.2**	**4.0**	**4.3**	**4.5**	**4.8**	**0.9**
Japan	1.9	2.8	2.8	3.0	2.9	2.9	2.9	2.9	0.1
Australia/New Zealand	0.8	1.0	1.1	1.2	1.1	1.4	1.6	1.9	2.6
Total Industrialized	**35.2**	**46.4**	**45.6**	**48.6**	**52.3**	**57.2**	**62.3**	**67.0**	**1.6**
EE/FSU									
Former Soviet Union	25.0	20.5	20.8	23.6	26.5	29.4	32.2	34.7	2.1
Eastern Europe	3.1	2.4	2.7	3.0	3.8	4.7	5.7	6.5	3.8
Total EE/FSU	**28.1**	**23.0**	**23.5**	**26.6**	**30.3**	**34.1**	**37.9**	**41.2**	**2.4**
Developing Countries									
Developing Asia	**3.0**	**6.6**	**7.5**	**8.4**	**9.2**	**11.6**	**15.2**	**17.4**	**3.5**
China	0.5	1.0	1.0	1.3	1.7	2.1	4.0	4.2	6.2
India	0.4	0.8	0.8	1.2	1.8	2.5	3.0	3.2	6.0
South Korea	0.1	0.7	0.7	0.8	1.1	1.3	1.4	1.4	2.8
Other Asia	2.0	4.2	4.9	5.0	4.6	5.7	6.9	8.4	2.3
Middle East	**3.7**	**7.3**	**7.9**	**7.9**	**9.4**	**9.8**	**11.2**	**12.7**	**2.0**
Turkey	0.1	0.5	0.6	0.6	0.7	0.8	0.9	1.0	2.4
Other Middle East	3.6	6.8	7.3	7.3	8.6	9.0	10.3	11.7	2.0
Africa	1.4	2.0	2.3	2.4	2.7	3.4	4.1	4.7	3.1
Central and South America	**2.0**	**3.3**	**3.5**	**3.9**	**4.9**	**6.0**	**7.9**	**10.3**	**4.6**
Brazil	0.1	0.3	0.3	0.3	0.7	1.3	1.9	2.5	8.7
Other Central/South America	1.9	3.0	3.2	3.5	4.2	4.7	6.0	7.8	3.8
Total Developing	**10.1**	**19.3**	**21.2**	**22.6**	**26.2**	**30.7**	**38.5**	**45.1**	**3.2**
Total World	**73.4**	**88.7**	**90.3**	**97.9**	**108.9**	**122.0**	**138.7**	**153.3**	**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 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table B13; and System for the Analysis of Global Energy Markets (2003).

Table C6. World Coal Consumption by Region, Low Economic Growth Case, 1990-2025
(Million Short Tons)

Region/Country	History			Projections					Average Annual Percent Change, 2001-2025
	1990	2000	2001	2005	2010	2015	2020	2025	
Industrialized Countries									
North America	**971**	**1,168**	**1,148**	**1,188**	**1,294**	**1,349**	**1,407**	**1,475**	**1.1**
United States[a]	903	1,084	1,060	1,097	1,204	1,254	1,313	1,381	1.1
Canada	59	69	73	78	74	74	71	69	-0.2
Mexico	9	15	15	14	16	21	23	26	2.3
Western Europe	**894**	**559**	**574**	**528**	**508**	**445**	**378**	**362**	**-1.9**
United Kingdom	119	64	71	70	64	61	54	48	-1.6
France	35	25	21	21	16	16	9	6	-5.2
Germany	528	264	265	263	263	256	224	186	-1.5
Italy	25	20	22	22	22	21	19	16	-1.3
Netherlands	15	14	23	23	16	12	11	10	-3.3
Other Western Europe	172	172	172	127	135	82	67	103	-2.1
Industrialized Asia	**231**	**303**	**312**	**311**	**333**	**339**	**354**	**362**	**0.6**
Japan	125	160	166	160	157	160	166	175	0.2
Australia/New Zealand	106	143	147	152	176	179	188	188	1.0
Total Industrialized	**2,095**	**2,029**	**2,034**	**2,028**	**2,134**	**2,133**	**2,139**	**2,200**	**0.3**
EE/FSU									
Former Soviet Union	848	421	446	535	490	478	416	367	-0.8
Eastern Europe	528	390	382	316	293	260	222	206	-2.5
Total EE/FSU	**1,376**	**811**	**828**	**852**	**783**	**738**	**638**	**573**	**-1.5**
Developing Countries									
Developing Asia	**1,590**	**1,959**	**2,084**	**2,063**	**2,204**	**2,375**	**2,462**	**2,663**	**1.0**
China	1,124	1,282	1,383	1,346	1,459	1,586	1,643	1,799	1.1
India	242	359	360	371	407	434	459	509	1.4
South Korea	49	72	76	73	84	90	91	88	0.6
Other Asia	175	246	265	273	254	264	268	267	0.0
Middle East	**66**	**94**	**95**	**112**	**112**	**115**	**119**	**121**	**1.0**
Turkey	60	80	81	85	85	84	88	90	0.4
Other Middle East	6	14	14	27	27	32	31	31	3.5
Africa	**152**	**187**	**191**	**216**	**208**	**225**	**238**	**252**	**1.2**
Central and South America	**27**	**34**	**32**	**37**	**40**	**43**	**46**	**49**	**1.9**
Brazil	17	21	21	21	24	26	30	30	1.5
Other Central/South America	10	13	11	16	17	17	16	19	2.4
Total Developing	**1,835**	**2,275**	**2,401**	**2,428**	**2,564**	**2,759**	**2,865**	**3,085**	**1.1**
Total World	**5,307**	**5,115**	**5,263**	**5,307**	**5,482**	**5,629**	**5,642**	**5,858**	**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. 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 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table B16; and System for the Analysis of Global Energy Markets (2003).

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	2005	2010	2015	2020	2025	
Industrialized Countries									
North America	**649**	**830**	**850**	**894**	**912**	**916**	**920**	**898**	**0.2**
United States[a]	577	754	769	793	800	805	807	807	0.2
Canada	69	69	73	92	103	102	103	81	0.5
Mexico	3	8	8	9	9	9	10	9	0.5
Western Europe	**703**	**845**	**870**	**856**	**869**	**830**	**756**	**631**	**-1.3**
United Kingdom	59	82	86	73	72	45	38	34	-3.8
France	298	394	401	406	427	425	422	402	0.0
Germany	145	161	163	166	145	139	96	42	-5.4
Italy	0	0	0	0	0	0	0	0	—
Netherlands	3	4	4	4	4	4	0	0	-100.0
Other Western Europe	198	204	217	206	220	218	200	152	-1.5
Industrialized Asia	**192**	**294**	**309**	**313**	**352**	**374**	**376**	**367**	**0.7**
Japan	192	294	309	313	352	374	376	367	0.7
Australia/New Zealand	0	0	0	0	0	0	0	0	—
Total Industrialized	**1,544**	**1,969**	**2,029**	**2,063**	**2,133**	**2,120**	**2,052**	**1,896**	**-0.3**
EE/FSU									
Former Soviet Union	201	204	210	217	228	220	183	148	-1.5
Eastern Europe	54	67	72	80	76	77	83	81	0.5
Total EE/FSU	**256**	**270**	**282**	**297**	**304**	**297**	**266**	**229**	**-0.9**
Developing Countries									
Developing Asia	**88**	**171**	**178**	**254**	**301**	**392**	**416**	**451**	**9.2**
China	0	16	17	57	66	125	122	139	9.2
India	6	14	18	21	27	40	45	47	4.1
South Korea	50	104	107	136	145	166	184	212	2.9
Other Asia	32	37	36	40	63	62	64	54	1.7
Middle East	**0**	**0**	**0**	**5**	**5**	**12**	**12**	**18**	**—**
Turkey	0	0	0	0	0	0	0	5	—
Other Middle East	0	0	0	5	5	12	12	12	—
Africa	**8**	**13**	**11**	**16**	**14**	**14**	**14**	**13**	**0.9**
Central and South America	**9**	**11**	**21**	**17**	**18**	**25**	**24**	**23**	**0.5**
Brazil	2	5	14	11	12	19	20	19	1.3
Other Central/South America	7	6	7	6	6	6	4	4	-2.1
Total Developing	**105**	**195**	**209**	**292**	**338**	**443**	**466**	**506**	**3.7**
Total World	**1,905**	**2,434**	**2,521**	**2,652**	**2,775**	**2,859**	**2,784**	**2,631**	**0.2**

[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 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table B8; and System for the Analysis of Global Energy Markets (2003).

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	2005	2010	2015	2020	2025	
Industrialized Countries									
North America	**9.5**	**10.6**	**9.4**	**11.2**	**11.9**	**12.5**	**12.9**	**13.2**	**1.4**
United States[a]	6.0	6.4	5.5	6.9	7.4	7.8	8.1	8.3	1.8
Canada	3.1	3.8	3.5	3.8	4.0	4.1	4.2	4.3	0.9
Mexico	0.3	0.5	0.4	0.5	0.5	0.6	0.6	0.6	1.3
Western Europe	**4.5**	**6.0**	**6.1**	**6.8**	**7.1**	**7.8**	**8.4**	**8.5**	**1.4**
United Kingdom	0.1	0.1	0.1	0.1	0.3	0.4	0.4	0.5	7.0
France	0.6	0.7	0.8	0.8	0.6	0.7	0.8	0.8	0.2
Germany	0.3	0.4	0.5	0.5	0.5	0.6	0.7	0.8	2.3
Italy	0.4	0.6	0.6	0.6	1.1	1.1	1.1	1.1	2.4
Netherlands	0.0	0.1	0.1	0.1	0.2	0.2	0.3	0.3	7.2
Other Western Europe	3.2	4.1	4.1	4.8	4.4	4.8	5.1	5.0	0.9
Industrialized Asia	**1.6**	**1.6**	**1.6**	**1.9**	**2.0**	**2.1**	**2.1**	**2.3**	**1.4**
Japan	1.1	1.1	1.1	1.3	1.4	1.4	1.5	1.6	1.6
Australia/New Zealand	0.4	0.5	0.5	0.6	0.6	0.6	0.6	0.6	1.1
Total Industrialized	**15.6**	**18.2**	**17.1**	**19.9**	**21.0**	**22.3**	**23.4**	**24.0**	**1.4**
EE/FSU									
Former Soviet Union	2.4	2.3	2.5	2.8	2.9	2.9	2.9	2.9	0.5
Eastern Europe	0.4	0.6	0.6	0.8	0.9	0.9	1.0	1.0	1.9
Total EE/FSU	**2.8**	**3.0**	**3.2**	**3.5**	**3.7**	**3.8**	**3.8**	**3.9**	**0.9**
Developing Countries									
Developing Asia	**3.2**	**4.5**	**5.1**	**5.6**	**7.8**	**8.6**	**9.4**	**10.0**	**2.9**
China	1.3	2.3	2.8	2.7	4.5	5.1	5.6	5.9	3.3
India	0.7	0.8	0.8	0.9	1.1	1.2	1.4	1.5	2.5
South Korea	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	7.1
Other Asia	1.1	1.4	1.5	1.9	2.1	2.3	2.4	2.4	2.1
Middle East	**0.4**	**0.5**	**0.4**	**0.4**	**0.7**	**0.9**	**1.0**	**1.1**	**4.1**
Turkey	0.2	0.3	0.3	0.3	0.4	0.4	0.5	0.6	3.4
Other Middle East	0.1	0.1	0.1	0.1	0.3	0.4	0.5	0.5	5.2
Africa	**0.6**	**0.7**	**0.8**	**0.9**	**1.1**	**1.1**	**1.2**	**1.2**	**1.7**
Central and South America	**3.9**	**5.9**	**5.6**	**5.9**	**6.5**	**6.5**	**6.7**	**6.8**	**0.8**
Brazil	2.2	3.3	2.9	3.0	3.4	3.5	3.5	3.5	0.8
Other Central/South America	1.7	2.6	2.7	2.9	3.0	3.1	3.2	3.3	0.9
Total Developing	**8.0**	**11.6**	**11.8**	**12.8**	**16.1**	**17.2**	**18.2**	**19.1**	**2.0**
Total World	**26.4**	**32.8**	**32.2**	**36.2**	**40.7**	**43.3**	**45.4**	**47.0**	**1.6**

[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. 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 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table B1; and System for the Analysis of Global Energy Markets (2003).

Table C9. World Net Electricity Consumption by Region, Low Economic Growth Case, 1990-2025
(Billion Kilowatthours)

Region/Country	History			Projections					Average Annual Percent Change, 2001-2025
	1990	2000	2001	2005	2010	2015	2020	2025	
Industrialized Countries									
North America	**3,369**	**4,297**	**4,293**	**4,370**	**4,840**	**5,281**	**5,665**	**6,062**	**1.4**
United States[a]	2,827	3,605	3,602	3,650	4,031	4,357	4,643	4,937	1.3
Canada	435	510	504	531	564	602	636	669	1.2
Mexico	107	182	187	188	245	322	387	457	3.8
Western Europe	**2,069**	**2,487**	**2,540**	**2,634**	**2,741**	**2,836**	**2,945**	**3,045**	**0.8**
United Kingdom	286	341	346	348	363	376	387	399	0.6
France	324	406	415	412	423	433	444	452	0.4
Germany	489	502	507	504	516	527	538	548	0.3
Italy	222	282	289	284	289	295	300	303	0.2
Netherlands	71	97	99	109	112	115	117	120	0.8
Other Western Europe	676	858	883	977	1,039	1,089	1,158	1,224	1.4
Industrialized Asia	**930**	**1,165**	**1,183**	**1,218**	**1,250**	**1,303**	**1,363**	**1,420**	**0.8**
Japan	765	944	964	989	1,001	1,033	1,064	1,092	0.5
Australia/New Zealand	166	221	219	229	249	270	299	328	1.7
Total Industrialized	**6,368**	**7,950**	**8,016**	**8,222**	**8,831**	**9,420**	**9,973**	**10,527**	**1.1**
EE/FSU									
Former Soviet Union	1,488	1,118	1,135	1,313	1,413	1,508	1,582	1,650	1.6
Eastern Europe	418	385	393	401	446	497	553	606	1.8
Total EE/FSU	**1,906**	**1,504**	**1,528**	**1,714**	**1,859**	**2,005**	**2,135**	**2,256**	**1.6**
Developing Countries									
Developing Asia	**1,259**	**2,542**	**2,730**	**2,917**	**3,412**	**3,916**	**4,432**	**4,918**	**2.5**
China	551	1,189	1,312	1,417	1,671	1,898	2,164	2,418	2.6
India	257	477	497	513	630	747	874	989	2.9
South Korea	93	254	270	287	343	387	415	435	2.0
Other Asia	358	621	650	699	769	883	979	1,076	2.1
Middle East	**263**	**522**	**543**	**528**	**591**	**655**	**718**	**783**	**1.5**
Turkey	51	114	113	111	126	140	155	169	1.7
Other Middle East	213	408	430	416	464	514	563	614	1.5
Africa	**286**	**388**	**396**	**420**	**478**	**546**	**611**	**676**	**2.3**
Central and South America	**463**	**724**	**721**	**744**	**861**	**984**	**1,147**	**1,356**	**2.7**
Brazil	229	359	336	359	407	463	524	589	2.4
Other Central/South America	234	365	385	386	454	520	623	767	2.9
Total Developing	**2,272**	**4,175**	**4,390**	**4,609**	**5,341**	**6,100**	**6,908**	**7,732**	**2.4**
Total World	**10,546**	**13,629**	**13,934**	**14,545**	**16,031**	**17,525**	**19,016**	**20,516**	**1.6**

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

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Electricity consumption equals generation plus imports minus exports minus distribution losses.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, *Annual Energy Outlook 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table B2; and System for the Analysis of Global Energy Markets (2003).

Table C10. World Carbon Dioxide Emissions by Region, Low Economic Growth Case, 1990-2025
(Million Metric Tons Carbon Equivalent)

Region/Country	History			Projections					Average Annual Percent Change, 2001-2025
	1990	2000	2001	2005	2010	2015	2020	2025	
Industrialized Countries									
North America	**1,564**	**1,836**	**1,810**	**1,880**	**2,056**	**2,202**	**2,326**	**2,461**	**1.3**
United States[a]	1,352	1,578	1,559	1,604	1,759	1,876	1,979	2,083	1.2
Canada	129	158	155	167	170	175	178	185	0.7
Mexico	84	99	96	109	127	150	170	193	2.9
Western Europe	**931**	**939**	**945**	**924**	**925**	**920**	**914**	**931**	**-0.1**
United Kingdom	164	151	153	152	154	154	157	157	0.1
France	102	109	108	107	102	100	100	102	-0.3
Germany	271	226	223	221	222	222	218	218	-0.1
Italy	113	121	121	120	123	123	123	122	0.0
Netherlands	58	62	68	67	64	60	60	60	-0.5
Other Western Europe	223	270	271	256	260	260	256	272	0.0
Industrialized Asia	**349**	**416**	**424**	**426**	**438**	**450**	**463**	**477**	**0.5**
Japan	269	310	316	311	310	313	317	322	0.1
Australia/New Zealand	80	106	109	116	128	137	146	155	1.5
Total Industrialized	**2,844**	**3,191**	**3,179**	**3,231**	**3,420**	**3,572**	**3,703**	**3,870**	**0.8**
EE/FSU									
Former Soviet Union	1,036	638	654	751	789	826	847	873	1.2
Eastern Europe	301	204	202	191	199	207	215	227	0.5
Total EE/FSU	**1,337**	**842**	**856**	**941**	**988**	**1,033**	**1,062**	**1,101**	**1.1**
Developing Countries									
Developing Asia	**1,089**	**1,557**	**1,640**	**1,660**	**1,789**	**1,971**	**2,139**	**2,324**	**1.5**
China	617	780	832	826	904	989	1,076	1,169	1.4
India	153	249	250	263	301	342	384	431	2.3
South Korea	64	116	121	127	145	158	163	166	1.3
Other Asia	256	411	437	445	439	483	516	559	1.0
Middle East	**231**	**344**	**354**	**351**	**388**	**410**	**448**	**488**	**1.3**
Turkey	35	50	50	56	61	68	73	78	1.9
Other Middle East	196	294	304	294	327	342	376	410	1.2
Africa	**179**	**221**	**230**	**238**	**241**	**261**	**282**	**305**	**1.2**
Central and South America	**192**	**262**	**263**	**271**	**305**	**342**	**396**	**464**	**2.4**
Brazil	68	93	95	96	113	131	150	171	2.5
Other Central/South America	124	169	168	175	192	211	246	294	2.3
Total Developing	**1,691**	**2,385**	**2,487**	**2,520**	**2,723**	**2,984**	**3,266**	**3,580**	**1.5**
Total World	**5,872**	**6,417**	**6,522**	**6,692**	**7,131**	**7,588**	**8,031**	**8,551**	**1.1**

[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 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table B19; and System for the Analysis of Global Energy Markets (2003).

Table C11. World Carbon Dioxide Emissions from Oil Use by Region, Low Economic Growth Case, 1990-2025
(Million Metric Tons Carbon Equivalent)

Region/Country	History 1990	History 2000	History 2001	Projections 2005	Projections 2010	Projections 2015	Projections 2020	Projections 2025	Average Annual Percent Change, 2001-2025
Industrialized Countries									
North America	**716**	**800**	**807**	**817**	**902**	**976**	**1,031**	**1,090**	**1.3**
United States[a]	590	659	668	669	742	803	853	902	1.3
Canada	61	70	70	73	75	75	75	76	0.3
Mexico	65	71	68	75	85	97	104	111	2.0
Western Europe	**474**	**505**	**503**	**496**	**490**	**486**	**478**	**479**	**-0.2**
United Kingdom	66	63	63	62	64	65	65	65	0.1
France	67	73	73	72	70	68	68	64	-0.5
Germany	103	97	95	94	95	94	95	92	-0.1
Italy	74	71	71	71	72	71	70	68	-0.2
Netherlands	27	27	27	26	28	27	27	27	0.0
Other Western Europe	138	174	174	170	162	160	153	164	-0.3
Industrialized Asia	**209**	**219**	**219**	**218**	**224**	**229**	**232**	**237**	**0.3**
Japan	179	182	182	178	180	182	182	183	0.0
Australia/New Zealand	31	37	37	40	43	47	50	54	1.6
Total Industrialized	**1,400**	**1,524**	**1,528**	**1,531**	**1,616**	**1,690**	**1,741**	**1,806**	**0.7**
EE/FSU									
Former Soviet Union	334	149	152	168	184	184	191	203	1.2
Eastern Europe	66	49	49	52	57	61	67	73	1.6
Total EE/FSU	**400**	**199**	**201**	**221**	**240**	**245**	**257**	**275**	**1.3**
Developing Countries									
Developing Asia	**304**	**522**	**533**	**551**	**603**	**669**	**740**	**800**	**1.7**
China	94	169	175	180	200	219	246	262	1.7
India	45	76	76	78	91	110	133	154	3.0
South Korea	38	65	67	72	79	83	84	84	1.0
Other Asia	128	211	215	222	232	257	277	301	1.4
Middle East	**155**	**205**	**208**	**198**	**214**	**229**	**244**	**260**	**0.9**
Turkey	17	22	22	23	26	30	32	35	1.9
Other Middle East	137	183	186	175	188	199	212	226	0.8
Africa	**83**	**97**	**100**	**93**	**95**	**96**	**100**	**106**	**0.2**
Central and South America	**145**	**189**	**188**	**188**	**203**	**221**	**243**	**273**	**1.6**
Brazil	57	75	76	78	88	96	103	114	1.7
Other Central/South America	88	114	112	110	116	125	140	158	1.5
Total Developing	**688**	**1,013**	**1,029**	**1,030**	**1,115**	**1,215**	**1,328**	**1,439**	**1.4**
Total World	**2,488**	**2,736**	**2,759**	**2,782**	**2,971**	**3,151**	**3,326**	**3,520**	**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 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table B19; and System for the Analysis of Global Energy Markets (2003).

Table C12. World Carbon Dioxide Emissions from Natural Gas Use by Region, Low Economic Growth Case, 1990-2025
(Million Metric Tons Carbon Equivalent)

Region/Country	History			Projections					Average Annual Percent Change, 2001-2025
	1990	2000	2001	2005	2010	2015	2020	2025	
Industrialized Countries									
North America	**329**	**410**	**393**	**433**	**473**	**517**	**562**	**605**	**1.8**
United States[a]	280	341	329	357	386	416	445	466	1.5
Canada	35	48	43	48	53	57	62	69	2.0
Mexico	15	21	21	28	35	43	55	70	5.2
Western Europe	**140**	**214**	**218**	**221**	**237**	**261**	**289**	**311**	**1.5**
United Kingdom	30	51	50	49	53	54	62	65	1.1
France	16	22	23	23	22	23	27	34	1.6
Germany	32	45	47	47	47	50	55	69	1.6
Italy	25	37	37	37	38	39	42	45	0.8
Netherlands	20	22	23	22	24	24	24	26	0.5
Other Western Europe	18	37	38	43	52	73	80	73	2.8
Industrialized Asia	**36**	**57**	**59**	**63**	**61**	**65**	**68**	**73**	**0.9**
Japan	24	41	43	45	44	44	44	43	0.1
Australia/New Zealand	12	15	16	18	17	22	24	30	2.6
Total Industrialized	**505**	**681**	**670**	**717**	**771**	**843**	**920**	**989**	**1.6**
EE/FSU									
Former Soviet Union	369	301	305	346	388	430	472	508	2.1
Eastern Europe	46	35	38	43	55	67	82	93	3.8
Total EE/FSU	**414**	**336**	**343**	**389**	**443**	**498**	**554**	**601**	**2.4**
Developing Countries									
Developing Asia	**46**	**100**	**114**	**126**	**139**	**175**	**231**	**263**	**3.5**
China	8	16	18	24	30	38	71	76	6.2
India	7	12	12	19	27	37	44	48	6.0
South Korea	2	11	12	15	19	24	29	32	4.3
Other Asia	29	61	73	69	63	76	86	106	1.6
Middle East	**56**	**111**	**119**	**120**	**142**	**147**	**170**	**192**	**2.0**
Turkey	2	8	8	13	14	18	19	22	4.0
Other Middle East	54	103	110	107	127	129	150	171	1.8
Africa	**22**	**32**	**35**	**38**	**42**	**53**	**64**	**74**	**3.1**
Central and South America	**32**	**51**	**55**	**61**	**77**	**94**	**124**	**161**	**4.6**
Brazil	2	5	5	5	10	19	28	38	8.7
Other Central/South America	30	46	50	56	66	75	95	123	3.9
Total Developing	**155**	**294**	**323**	**344**	**399**	**469**	**588**	**690**	**3.2**
Total World	**1,075**	**1,310**	**1,336**	**1,450**	**1,614**	**1,810**	**2,061**	**2,280**	**2.3**

[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 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table B19; and System for the Analysis of Global Energy Markets (2003).

Table C13. World Carbon Dioxide Emissions from Coal Use by Region, Low Economic Growth Case, 1990-2025
(Million Metric Tons Carbon Equivalent)

Region/Country	History			Projections					Average Annual Percent Change, 2001-2025
	1990	2000	2001	2005	2010	2015	2020	2025	
Industrialized Countries									
North America	**527**	**625**	**610**	**630**	**681**	**709**	**733**	**767**	**1.0**
United States[a]	489	579	561	578	631	657	681	715	1.0
Canada	34	40	42	45	43	43	41	40	-0.2
Mexico	4	7	7	6	7	9	11	12	2.3
Western Europe	**316**	**219**	**224**	**207**	**198**	**173**	**148**	**141**	**-1.9**
United Kingdom	68	36	41	40	37	35	31	28	-1.6
France	20	14	12	12	9	9	5	3	-5.2
Germany	137	83	81	80	80	78	69	57	-1.5
Italy	15	13	13	13	13	13	11	10	-1.3
Netherlands	11	13	18	18	12	10	9	8	-3.3
Other Western Europe	66	59	59	43	46	28	23	35	-2.1
Industrialized Asia	**104**	**141**	**147**	**145**	**153**	**156**	**163**	**167**	**0.5**
Japan	66	87	91	88	86	88	91	96	0.2
Australia/New Zealand	37	54	56	58	67	68	72	72	1.0
Total Industrialized	**947**	**985**	**981**	**983**	**1,032**	**1,038**	**1,043**	**1,075**	**0.4**
EE/FSU									
Former Soviet Union	333	187	197	237	217	211	184	162	-0.8
Eastern Europe	189	120	115	95	88	78	67	62	-2.5
Total EE/FSU	**522**	**307**	**312**	**332**	**305**	**289**	**251**	**224**	**-1.4**
Developing Countries									
Developing Asia	**739**	**936**	**993**	**983**	**1,048**	**1,128**	**1,168**	**1,261**	**1.0**
China	514	595	639	622	674	733	759	831	1.1
India	101	161	162	167	183	195	207	229	1.4
South Korea	24	40	42	40	47	50	51	49	0.6
Other Asia	99	139	150	154	144	150	152	152	0.1
Middle East	**20**	**28**	**27**	**32**	**32**	**33**	**34**	**35**	**1.0**
Turkey	16	20	19	20	20	20	21	22	0.4
Other Middle East	4	8	8	12	12	13	13	13	2.2
Africa	**74**	**93**	**95**	**107**	**103**	**112**	**118**	**125**	**1.2**
Central and South America	**15**	**21**	**20**	**23**	**25**	**27**	**29**	**31**	**1.9**
Brazil	9	13	13	13	15	16	19	19	1.5
Other Central/South America	6	8	7	10	10	11	10	12	2.4
Total Developing	**848**	**1,078**	**1,134**	**1,146**	**1,209**	**1,300**	**1,350**	**1,452**	**1.0**
Total World	**2,317**	**2,370**	**2,427**	**2,460**	**2,546**	**2,628**	**2,644**	**2,751**	**0.5**

[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 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table B19; and System for the Analysis of Global Energy Markets (2003).

Table C14. 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	2005	2010	2015	2020	2025	
Industrialized Countries									
North America	**2,534**	**2,990**	**2,912**	**3,093**	**3,356**	**3,581**	**3,771**	**3,962**	**1.3**
United States[a]	2,131	2,503	2,446	2,568	2,789	2,966	3,116	3,261	1.2
Canada	278	331	315	351	366	378	387	397	1.0
Mexico	126	156	151	174	201	236	268	305	3.0
Western Europe	**1,509**	**1,685**	**1,718**	**1,702**	**1,726**	**1,745**	**1,753**	**1,757**	**0.1**
United Kingdom	234	246	247	245	249	252	253	254	0.1
France	222	261	265	263	267	270	273	275	0.2
Germany	373	357	362	358	361	364	366	368	0.1
Italy	177	201	204	203	205	208	210	211	0.1
Netherlands	85	99	107	106	107	108	109	109	0.1
Other Western Europe	418	520	533	528	537	543	542	541	0.1
Industrialized Asia	**563**	**692**	**699**	**711**	**736**	**760**	**779**	**801**	**0.6**
Japan	452	548	552	552	564	575	581	588	0.3
Australia/New Zealand	111	144	147	159	172	186	198	213	1.6
Total Industrialized	**4,606**	**5,366**	**5,329**	**5,506**	**5,819**	**6,086**	**6,304**	**6,520**	**0.8**
EE/FSU									
Former Soviet Union	1,529	1,029	1,055	1,198	1,279	1,346	1,390	1,438	1.3
Eastern Europe	393	285	287	291	311	332	356	381	1.2
Total EE/FSU	**1,923**	**1,314**	**1,342**	**1,489**	**1,590**	**1,678**	**1,746**	**1,819**	**1.3**
Developing Countries									
Developing Asia	**1,322**	**2,029**	**2,143**	**2,211**	**2,441**	**2,726**	**2,994**	**3,254**	**1.8**
China	681	931	1,000	1,006	1,147	1,274	1,403	1,520	1.8
India	196	319	322	345	401	464	528	592	2.6
South Korea	95	199	203	220	249	269	280	288	1.5
Other Asia	350	580	617	641	644	718	784	855	1.4
Middle East	**329**	**511**	**524**	**517**	**585**	**622**	**685**	**751**	**1.5**
Turkey	50	76	73	77	86	94	103	111	1.8
Other Middle East	280	435	451	440	499	527	582	640	1.5
Africa	**235**	**301**	**314**	**327**	**338**	**367**	**398**	**430**	**1.3**
Central and South America	**364**	**529**	**527**	**549**	**614**	**673**	**763**	**876**	**2.1**
Brazil	150	228	221	225	251	281	313	346	1.9
Other Central/South America	214	302	306	324	363	392	450	530	2.3
Total Developing	**2,250**	**3,371**	**3,508**	**3,604**	**3,978**	**4,388**	**4,840**	**5,311**	**1.7**
Total World	**8,779**	**10,052**	**10,179**	**10,599**	**11,387**	**12,151**	**12,890**	**13,650**	**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 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table B1; and System for the Analysis of Global Energy Markets (2003).

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	2005	2010	2015	2020	2025
OPEC							
Persian Gulf							
Iran	3.2	3.7	3.9	4.2	4.5	4.7	4.9
Iraq	2.2	2.8	3.2	3.6	4.2	4.6	5.2
Kuwait	1.7	2.4	2.8	3.3	3.9	4.5	5.1
Qatar	0.5	0.6	0.6	0.6	0.7	0.8	0.8
Saudi Arabia	8.6	10.2	11.1	13.6	15.7	19.5	23.8
United Arab Emitates	2.5	2.7	2.9	3.4	4.0	4.8	5.4
Total Persian Gulf	**18.7**	**22.4**	**24.5**	**28.7**	**33.0**	**38.9**	**45.2**
Other OPEC							
Algeria	1.3	1.6	1.7	2.0	2.1	2.4	2.8
Indonesia	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Libya	1.5	1.7	1.7	2.0	2.2	2.6	2.9
Nigeria	1.8	2.2	2.3	2.6	3.1	3.5	3.8
Venezuela	2.4	3.2	3.4	3.9	4.4	5.0	5.6
Total Other OPEC	**8.5**	**10.2**	**10.6**	**12.0**	**13.3**	**15.0**	**16.6**
Total OPEC	**27.2**	**32.6**	**35.1**	**40.7**	**46.3**	**53.9**	**61.8**
Non-OPEC							
Industrialized							
United States	9.7	9.0	9.0	9.2	9.0	9.4	9.4
Canada	2.0	2.8	3.1	3.4	3.6	3.8	4.1
Mexico	3.0	3.6	3.8	4.2	4.5	4.6	4.8
Australia	0.7	0.7	0.7	0.8	0.8	0.8	0.8
North Sea	4.2	6.5	6.1	5.9	5.5	5.0	4.5
Other	0.5	0.6	0.7	0.8	0.7	0.7	0.7
Total Industrialized	**20.1**	**23.2**	**23.4**	**24.3**	**24.1**	**24.3**	**24.3**
Eurasia							
China	2.8	3.3	3.5	3.6	3.5	3.5	3.4
Former Soviet Union	11.4	8.8	9.7	11.6	13.3	14.4	15.9
Eastern Europe	0.3	0.2	0.3	0.3	0.3	0.4	0.4
Total Eurasia	**14.5**	**12.3**	**13.5**	**15.5**	**17.1**	**18.3**	**19.7**
Other Non-OPEC							
Central and South America	2.3	3.8	4.3	4.7	5.7	6.2	6.7
Middle East	1.4	1.8	2.0	2.2	2.4	2.5	2.7
Africa	2.2	3.0	3.4	3.9	4.9	5.6	6.7
Asia	1.7	2.5	2.5	2.6	2.8	2.7	2.6
Total Other Non-OPEC	**7.6**	**11.1**	**12.2**	**13.4**	**15.8**	**17.0**	**18.7**
Total Non-OPEC	**42.2**	**46.6**	**49.1**	**53.2**	**57.0**	**59.6**	**62.7**
Total World	**69.4**	**79.2**	**84.2**	**93.9**	**103.3**	**113.5**	**124.5**

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 (2003); 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)		Projections				
	1990	2001	2005	2010	2015	2020	2025
OPEC							
Persian Gulf							
Iran	3.2	3.7	3.7	3.8	4.0	4.3	4.6
Iraq	2.2	2.8	3.3	3.5	3.9	4.2	4.8
Kuwait	1.7	2.4	2.5	2.7	3.1	3.6	4.3
Qatar	0.5	0.6	0.6	0.6	0.7	0.8	0.8
Saudi Arabia	8.6	10.2	10.5	11.4	12.3	14.9	17.6
United Arab Emitates	2.5	2.7	2.6	2.9	3.5	4.3	4.9
Total Persian Gulf	**18.7**	**22.4**	**23.2**	**24.9**	**27.5**	**32.1**	**37.0**
Other OPEC							
Algeria	1.3	1.6	1.6	1.8	1.9	2.1	2.2
Indonesia	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Libya	1.5	1.7	1.6	1.7	1.9	2.3	2.4
Nigeria	1.8	2.2	2.1	2.4	2.7	3.1	3.6
Venezuela	2.4	3.2	3.0	3.4	3.9	4.4	5.0
Total Other OPEC	**8.5**	**10.2**	**9.8**	**10.8**	**11.9**	**13.4**	**14.7**
Total OPEC	**27.2**	**32.6**	**33.0**	**35.7**	**39.4**	**45.5**	**51.7**
Non-OPEC							
Industrialized							
United States	9.7	9.0	9.1	9.4	9.4	9.7	10.0
Canada	2.0	2.8	3.3	3.6	3.9	4.1	4.4
Mexico	3.0	3.6	3.9	4.4	4.8	5.0	5.3
Australia	0.7	0.7	0.7	0.8	0.8	0.9	0.9
North Sea	4.2	6.5	6.1	6.0	5.7	5.3	4.9
Other	0.5	0.6	0.7	0.8	0.8	0.8	0.9
Total Industrialized	**20.1**	**23.2**	**23.8**	**25.0**	**25.4**	**25.8**	**26.4**
Eurasia							
China	2.8	3.3	3.6	3.7	3.7	3.8	3.9
Former Soviet Union	11.4	8.8	9.9	12.0	13.6	14.9	16.0
Eastern Europe	0.3	0.2	0.3	0.3	0.4	0.5	0.5
Total Eurasia	**14.5**	**12.3**	**13.8**	**16.0**	**17.7**	**19.2**	**20.4**
Other Non-OPEC							
Central and South America	2.3	3.8	4.4	4.9	5.9	6.3	7.5
Middle East	1.4	1.8	2.0	2.2	2.5	2.9	3.3
Africa	2.2	3.0	3.5	4.2	5.1	6.0	7.1
Asia	1.7	2.5	2.6	2.8	3.1	3.0	3.1
Total Other Non-OPEC	**7.6**	**11.1**	**12.5**	**14.1**	**16.6**	**18.2**	**21.0**
Total Non-OPEC	**42.2**	**46.6**	**50.1**	**55.1**	**59.7**	**63.2**	**67.8**
Total World	**69.4**	**79.2**	**83.1**	**90.8**	**99.1**	**108.7**	**119.5**

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 (2003); 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	2005	2010	2015	2020	2025
OPEC							
Persian Gulf							
Iran	3.2	3.7	4.1	4.5	4.9	5.4	5.7
Iraq	2.2	2.8	3.4	4.1	4.7	5.6	6.1
Kuwait	1.7	2.4	2.9	3.6	4.3	5.1	5.7
Qatar	0.5	0.6	0.6	0.6	0.8	0.8	0.8
Saudi Arabia	8.6	10.2	11.7	15.3	19.2	24.4	30.3
United Arab Emitates	2.5	2.7	3.1	3.7	4.5	5.3	5.9
Total Persian Gulf	**18.7**	**22.4**	**25.8**	**31.8**	**38.4**	**46.6**	**54.5**
Other OPEC							
Algeria	1.3	1.6	1.8	2.1	2.3	2.6	3.0
Indonesia	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Libya	1.5	1.7	1.7	2.1	2.4	2.7	3.1
Nigeria	1.8	2.2	2.5	2.9	3.4	4.1	4.6
Venezuela	2.4	3.2	3.5	4.2	4.7	5.2	6.1
Total Other OPEC	**8.5**	**10.2**	**11.0**	**12.8**	**14.3**	**16.1**	**18.3**
Total OPEC	**27.2**	**32.6**	**36.8**	**44.6**	**52.7**	**62.7**	**72.8**
Non-OPEC							
Industrialized							
United States	9.7	9.0	9.0	9.1	8.9	9.2	9.0
Canada	2.0	2.8	3.0	3.2	3.3	3.5	3.7
Mexico	3.0	3.6	3.6	4.0	4.3	4.3	4.4
Australia	0.7	0.7	0.7	0.7	0.7	0.8	0.8
North Sea	4.2	6.5	5.8	5.7	5.3	4.6	4.2
Other	0.5	0.6	0.7	0.7	0.6	0.6	0.6
Total Industrialized	**20.1**	**23.2**	**22.8**	**23.4**	**23.1**	**23.0**	**22.7**
Eurasia							
China	2.8	3.3	3.4	3.5	3.4	3.3	3.3
Former Soviet Union	11.4	8.8	9.5	11.2	12.6	13.2	14.7
Eastern Europe	0.3	0.2	0.3	0.3	0.3	0.3	0.3
Total Eurasia	**14.5**	**12.3**	**13.2**	**15.0**	**16.3**	**16.8**	**18.3**
Other Non-OPEC							
Central and South America	2.3	3.8	4.1	4.4	5.3	5.7	6.0
Middle East	1.4	1.8	1.9	2.1	2.2	2.3	2.5
Africa	2.2	3.0	3.4	3.8	4.6	5.2	6.1
Asia	1.7	2.5	2.4	2.5	2.6	2.5	2.5
Total Other Non-OPEC	**7.6**	**11.1**	**11.8**	**12.8**	**14.7**	**15.7**	**17.1**
Total Non-OPEC	**42.2**	**46.6**	**47.8**	**51.2**	**54.1**	**55.5**	**58.1**
Total World	**69.4**	**79.2**	**84.6**	**95.8**	**106.8**	**118.2**	**130.9**

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 (2003); 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)		Projections				
	1990	2001	2005	2010	2015	2020	2025
OPEC							
Persian Gulf	16.2	20.6	21.7	24.8	29.2	34.6	40.5
Other OPEC	8.3	9.8	9.9	11.3	12.2	13.6	15.1
Total OPEC	**24.5**	**30.4**	**31.6**	**36.1**	**41.4**	**48.2**	**55.6**
Non-OPEC							
Industrialized							
United States	9.7	9.0	9.0	9.2	9.0	9.4	9.4
Canada	2.0	2.8	3.1	3.4	3.6	3.8	4.1
Mexico	3.0	3.6	3.8	4.2	4.5	4.6	4.8
Western Europe	4.6	6.9	6.6	6.5	6.0	5.6	5.1
Other	0.8	0.9	0.9	1.0	1.0	0.9	0.9
Total Industrialized	**20.1**	**23.2**	**23.4**	**24.3**	**24.1**	**24.3**	**24.3**
Eurasia							
China	2.8	3.3	3.5	3.6	3.5	3.5	3.4
Former Soviet Union	11.4	8.8	9.7	11.6	13.3	14.4	15.9
Eastern Europe	0.3	0.2	0.3	0.3	0.3	0.4	0.4
Total Eurasia	**14.5**	**12.3**	**13.5**	**15.5**	**17.1**	**18.3**	**19.7**
Other Non-OPEC							
Central and South America	2.4	3.8	4.3	4.7	5.7	6.2	6.7
Pacific Rim	1.7	2.5	2.5	2.6	2.8	2.7	2.6
Other	3.5	4.8	5.4	6.1	7.3	8.1	9.4
Total Other Non-OPEC	**7.6**	**11.1**	**12.2**	**13.4**	**15.8**	**17.0**	**18.7**
Total Non-OPEC	**42.2**	**46.6**	**49.1**	**53.2**	**57.0**	**59.6**	**62.7**
Total World	**66.7**	**77.0**	**80.7**	**89.3**	**98.4**	**107.8**	**118.3**
Persian Gulf Production as a Percentage of World Consumption	**24.6**	**26.7**	**26.8**	**27.7**	**29.6**	**32.0**	**34.1**

Note: OPEC = Organization of Petroleum Exporting Countries. 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. 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 (2003); 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	2005	2010	2015	2020	2025
OPEC							
Persian Gulf	16.2	20.6	19.8	20.8	23.1	27.4	32.1
Other OPEC	8.3	9.8	9.5	10.1	11.2	12.1	13.1
Total OPEC	**24.5**	**30.4**	**29.3**	**30.9**	**34.3**	**39.5**	**45.2**
Non-OPEC							
Industrialized							
United States	9.7	9.0	9.1	9.4	9.4	9.7	10.0
Canada	2.0	2.8	3.3	3.6	3.9	4.1	4.4
Mexico	3.0	3.6	3.9	4.4	4.8	5.0	5.3
Western Europe	4.6	6.9	6.6	6.5	6.1	5.8	5.5
Other	0.8	0.9	0.9	1.1	1.2	1.2	1.2
Total Industrialized	**20.1**	**23.2**	**23.8**	**25.0**	**25.4**	**25.8**	**26.4**
Eurasia							
China	2.8	3.3	3.6	3.7	3.7	3.8	3.9
Former Soviet Union	11.4	8.8	9.9	12.0	13.6	14.9	16.0
Eastern Europe	0.3	0.2	0.3	0.3	0.4	0.5	0.5
Total Eurasia	**14.5**	**12.3**	**13.8**	**16.0**	**17.7**	**19.2**	**20.4**
Other Non-OPEC							
Central and South America	2.4	3.8	4.4	4.9	5.9	6.3	7.5
Pacific Rim	1.7	2.5	2.6	2.8	3.1	3.0	3.1
Other	3.5	4.8	5.5	6.4	7.6	8.9	10.4
Total Other Non-OPEC	**7.6**	**11.1**	**12.5**	**14.1**	**16.6**	**18.2**	**21.0**
Total Non-OPEC	**42.2**	**46.6**	**50.1**	**55.1**	**59.7**	**63.2**	**67.8**
Total World	**66.7**	**77.0**	**79.4**	**86.0**	**94.0**	**102.7**	**113.0**
Persian Gulf Production as a Percentage of World Consumption	**24.6**	**26.7**	**24.9**	**24.1**	**24.5**	**26.6**	**28.3**

Note: OPEC = Organization of Petroleum Exporting Countries. 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. 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 (2003); 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	2005	2010	2015	2020	2025
OPEC							
Persian Gulf	16.2	20.6	23.4	28.4	34.5	43.2	52.1
Other OPEC	8.3	9.8	10.1	11.8	13.5	14.1	14.8
Total OPEC	**24.5**	**30.4**	**33.5**	**40.2**	**48.0**	**57.3**	**66.9**
Non-OPEC							
Industrialized							
United States	9.7	9.0	9.0	9.1	8.9	9.2	9.0
Canada	2.0	2.8	3.0	3.2	3.3	3.5	3.7
Mexico	3.0	3.6	3.6	4.0	4.3	4.3	4.4
Western Europe	4.6	6.9	6.3	6.2	5.7	5.2	4.8
Other	0.8	0.9	0.9	0.9	0.9	0.8	0.8
Total Industrialized	**20.1**	**23.2**	**22.8**	**23.4**	**23.1**	**23.0**	**22.7**
Eurasia							
China	2.8	3.3	3.4	3.5	3.4	3.3	3.3
Former Soviet Union	11.4	8.8	9.5	11.2	12.6	13.2	14.7
Eastern Europe	0.3	0.2	0.3	0.3	0.3	0.3	0.3
Total Eurasia	**14.5**	**12.3**	**13.2**	**15.0**	**16.3**	**16.8**	**18.3**
Other Non-OPEC							
Central and South America	2.4	3.8	4.1	4.4	5.3	5.7	6.0
Pacific Rim	1.7	2.5	2.4	2.5	2.6	2.5	2.5
Other	3.5	4.8	5.3	5.9	6.8	7.5	8.6
Total Other Non-OPEC	**7.6**	**11.1**	**11.8**	**12.8**	**14.7**	**15.7**	**17.1**
Total Non-OPEC	**42.2**	**46.6**	**47.8**	**51.2**	**54.1**	**55.5**	**58.1**
Total World	**66.7**	**77.0**	**81.3**	**91.4**	**102.1**	**112.8**	**125.0**
Persian Gulf Production as a Percentage of World Consumption	**24.6**	**26.7**	**28.7**	**31.0**	**33.7**	**38.2**	**41.6**

Note: OPEC = Organization of Petroleum Exporting Countries. 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. 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 (2003); 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, 1999-2025
(Megawatts)

Region/Country	History			Projections				
	1999	2000	2001	2005	2010	2015	2020	2025
Industrialized Countries								
North America	**112,446**	**109,353**	**109,530**	**114,758**	**115,163**	**115,353**	**115,468**	**112,611**
United States	97,470	97,975	98,152	100,152	99,288	99,479	99,593	99,593
Canada	13,616	10,018	10,018	13,232	14,433	14,433	14,433	11,576
Mexico	1,360	1,360	1,360	1,374	1,442	1,442	1,442	1,442
Western Europe	**124,902**	**125,882**	**125,882**	**124,185**	**126,101**	**120,913**	**111,721**	**96,355**
Belgium	5,712	5,712	5,712	5,769	6,055	5,639	4,204	0
Finland	2,656	2,656	2,656	2,656	3,656	3,656	3,656	3,656
France	61,623	63,073	63,073	63,468	66,610	66,610	66,610	64,681
Germany	21,345	21,345	21,345	21,558	18,831	18,153	12,685	5,690
Netherlands	450	450	450	450	450	450	0	0
Spain	7,524	7,524	7,524	7,599	7,813	7,813	7,341	7,341
Sweden	9,432	9,432	9,432	8,466	8,249	8,249	8,249	7,321
Switzerland	3,192	3,192	3,192	3,224	3,384	3,384	2,997	2,242
United Kingdom	12,968	12,498	12,498	10,994	11,053	6,959	5,979	5,424
Industrialized Asia	**43,491**	**43,245**	**43,245**	**44,958**	**49,398**	**52,238**	**52,238**	**51,899**
Japan	43,491	43,245	43,245	44,958	49,398	52,238	52,238	51,899
Total Industrialized	**280,839**	**278,480**	**278,657**	**283,900**	**290,662**	**288,504**	**279,426**	**260,865**
EE/FSU								
Eastern Europe	**10,292**	**10,680**	**11,592**	**11,805**	**10,659**	**10,659**	**11,309**	**11,309**
Bulgaria	3,538	3,538	3,538	2,749	2,020	2,020	2,020	2,020
Czech Republic	1,648	1,648	2,560	3,507	3,680	3,680	3,680	3,680
Hungary	1,755	1,755	1,755	1,773	1,860	1,860	1,860	1,860
Romania	655	655	655	662	694	694	1,344	1,344
Slovakia	2,020	2,408	2,408	2,432	1,688	1,688	1,688	1,688
Slovenia	676	676	676	683	717	717	717	717
Former Soviet Union	**34,704**	**33,779**	**34,729**	**34,814**	**35,745**	**34,364**	**28,546**	**23,412**
Armenia	376	376	376	376	376	0	0	0
Lithuania	2,370	2,370	2,370	1,185	0	0	0	0
Russia	19,843	19,843	20,793	21,951	23,507	22,504	16,685	14,463
Ukraine	12,115	11,190	11,190	11,302	11,861	11,861	11,861	8,949
Total EE/FSU	**44,996**	**44,459**	**46,321**	**46,619**	**46,404**	**45,024**	**39,855**	**34,722**

See notes at end of table.

Table E1. World Nuclear Generating Capacity by Region and Country, Reference Case, 1999-2025 (Continued)
(Megawatts)

Region/Country	History			Projections				
	1999	2000	2001	2005	2010	2015	2020	2025
Developing Countries								
Developing Asia	**21,861**	**22,767**	**22,969**	**32,323**	**39,077**	**51,535**	**55,485**	**61,695**
China	2,167	2,167	2,167	7,603	8,603	16,603	16,603	19,593
India	1,695	2,301	2,503	2,413	4,153	5,886	6,536	6,986
Pakistan	125	425	425	425	425	300	900	900
South Korea	12,990	12,990	12,990	16,949	18,007	20,857	23,557	27,607
Taiwan	4,884	4,884	4,884	4,933	7,889	7,889	7,889	6,609
Middle East	**0**	**0**	**0**	**915**	**915**	**2,111**	**2,111**	**3,111**
Iran	0	0	0	915	915	2,111	2,111	2,111
Turkey	0	0	0	0	0	0	0	1,000
Africa	**1,800**	**1,800**	**1,800**	**1,818**	**1,908**	**1,908**	**1,908**	**1,908**
South Africa	1,800	1,800	1,800	1,818	1,908	1,908	1,908	1,908
Central and South America	**1,561**	**2,836**	**2,836**	**2,836**	**2,836**	**4,065**	**3,730**	**3,730**
Argentina	935	935	935	935	935	935	600	600
Brazil	626	1,901	1,901	1,901	1,901	3,130	3,130	3,130
Total Developing	**25,466**	**27,403**	**27,605**	**37,892**	**44,736**	**59,619**	**63,234**	**70,444**
Total World	**349,233**	**350,342**	**352,583**	**368,411**	**381,802**	**393,147**	**382,516**	**366,030**

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 2002). **Projections:** Energy Information Administration (EIA), *Annual Energy Outlook 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), 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, 1999-2025
(Megawatts)

Region/Country	History			Projections				
	1999	2000	2001	2005	2010	2015	2020	2025
Industrialized Countries								
North America	**112,446**	**109,353**	**109,530**	**114,758**	**115,163**	**116,053**	**117,868**	**119,568**
United States	97,470	97,975	98,152	100,152	99,288	99,479	99,593	99,593
Canada	13,616	10,018	10,018	13,232	14,433	15,133	15,833	16,533
Mexico	1,360	1,360	1,360	1,374	1,442	1,442	2,442	3,442
Western Europe	**124,902**	**125,882**	**125,882**	**126,351**	**131,447**	**138,531**	**147,539**	**158,293**
Belgium	5,712	5,712	5,712	5,769	6,055	6,055	6,055	8,055
Finland	2,656	2,656	2,656	2,656	3,656	4,656	4,656	5,656
France	61,623	63,073	63,073	63,704	66,610	69,510	72,410	75,310
Germany	21,345	21,345	21,345	21,558	22,265	22,265	23,200	23,284
Italy	0	0	0	0	0	0	1,000	2,000
Netherlands	450	450	450	450	450	450	450	1,450
Spain	7,524	7,524	7,524	7,599	7,975	8,813	9,813	10,813
Sweden	9,432	9,432	9,432	9,526	9,998	9,362	9,362	10,362
Switzerland	3,192	3,192	3,192	3,224	3,384	3,384	4,384	4,384
United Kingdom	12,968	12,498	12,498	11,864	11,053	14,036	16,209	16,979
Industrialized Asia	**43,491**	**43,491**	**43,245**	**46,974**	**51,645**	**59,956**	**70,356**	**73,706**
Japan	43,491	43,491	43,245	46,974	51,645	59,956	70,356	73,706
Total Industrialized	**280,839**	**278,726**	**278,657**	**288,083**	**298,254**	**314,541**	**335,762**	**351,567**
EE/FSU								
Eastern Europe	**10,292**	**10,680**	**11,592**	**12,629**	**12,607**	**16,165**	**19,688**	**25,688**
Bulgaria	3,538	3,538	3,538	3,573	2,885	3,838	3,973	4,973
Czech Republic	1,648	1,648	2,560	3,507	3,680	3,680	4,680	5,680
Hungary	1,755	1,755	1,755	1,773	1,860	1,860	2,860	3,860
Poland	0	0	0	0	0	0	1,000	3,000
Romania	655	655	655	662	1,344	1,994	1,994	2,994
Slovakia	2,020	2,408	2,408	2,432	2,120	4,076	4,464	4,464
Slovenia	676	676	676	683	717	717	717	717
Former Soviet Union	**34,704**	**33,779**	**34,729**	**36,924**	**44,118**	**48,713**	**58,487**	**70,600**
Armenia	376	376	376	376	376	376	0	2,000
Belarus	0	0	0	0	0	0	0	2,000
Estonia	0	0	0	0	0	0	0	1,000
Kazakhstan	0	0	0	0	0	0	1,920	2,880
Lithuania	2,370	2,370	2,370	2,370	1,185	1,000	1,000	2,000
Russia	19,843	19,843	20,793	22,876	28,796	33,576	39,906	43,058
Ukraine	12,115	11,190	11,190	11,302	13,761	13,761	15,661	17,661
Total EE/FSU	**44,996**	**44,459**	**46,321**	**49,553**	**56,725**	**64,878**	**78,175**	**96,288**

See notes at end of table.

Table E2. World Nuclear Generating Capacity by Region and Country, High Growth Case, 1999-2025 (Contniued)
(Megawatts)

Region/Country	History			Projections				
	1999	2000	2001	2005	2010	2015	2020	2025
Developing Countries								
Developing Asia	**21,861**	**22,767**	**22,969**	**33,863**	**47,834**	**63,271**	**83,002**	**98,160**
Bangladesh	0	0	0	0	0	0	0	600
China	2,167	2,167	2,167	8,603	11,703	17,703	20,703	22,703
India	1,695	2,301	2,503	2,953	6,721	8,791	12,691	13,799
Indonesia	0	0	0	0	0	0	2,000	3,000
Malaysia	0	0	0	0	0	0	1,000	2,000
Pakistan	125	425	425	425	1,025	1,625	2,700	4,700
Philippines	0	0	0	0	0	0	0	2,000
South Korea	12,990	12,990	12,990	16,949	20,496	24,907	30,307	34,357
Taiwan	4,884	4,884	4,884	4,933	7,889	9,245	10,601	10,601
Thailand	0	0	0	0	0	1,000	2,000	3,000
Vietnam	0	0	0	0	0	0	1,000	2,000
Middle East	**0**	**0**	**0**	**915**	**2,111**	**2,111**	**5,111**	**7,111**
Iran	0	0	0	915	2,111	2,111	3,111	4,111
Turkey	0	0	0	0	0	0	1,000	1,000
Syria	0	0	0	0	0	0	1,000	2,000
Africa	**1,800**	**1,800**	**1,800**	**1,818**	**2,038**	**2,168**	**3,428**	**6,688**
Egypt	0	0	0	0	0	0	0	2,000
Morocco	0	0	0	0	0	0	1,000	2,000
South Africa	1,800	1,800	1,800	1,818	2,038	2,168	2,428	2,688
Central and South America	**1,561**	**2,836**	**2,836**	**2,836**	**4,065**	**4,065**	**6,065**	**7,065**
Argentina	935	935	935	935	935	935	1,935	1,935
Brazil	626	1,901	1,901	1,901	3,130	3,130	4,130	5,130
Total Developing	**25,466**	**27,403**	**27,605**	**39,432**	**56,048**	**71,615**	**97,606**	**119,024**
Total World	**349,233**	**350,588**	**352,583**	**377,068**	**411,027**	**451,034**	**511,544**	**566,879**

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 2002). **Projections:** Energy Information Administration (EIA), *Annual Energy Outlook 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), 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, 1999-2025
(Megawatts)

Region/Country	History			Projections				
	1999	2000	2001	2005	2010	2015	2020	2025
Industrialized Countries								
North America	**112,446**	**109,353**	**109,530**	**114,758**	**114,490**	**111,824**	**110,308**	**108,392**
United States	97,470	97,975	98,152	100,152	99,288	99,479	99,593	99,593
Canada	13,616	10,018	10,018	13,232	13,760	10,903	9,273	7,357
Mexico	1,360	1,360	1,360	1,374	1,442	1,442	1,442	1,442
Western Europe	**124,902**	**125,882**	**125,882**	**122,408**	**114,986**	**99,539**	**72,868**	**40,962**
Belgium	5,712	5,712	5,712	5,769	4,204	4,204	0	0
Finland	2,656	2,656	2,656	2,656	2,656	3,656	2,328	1,000
France	61,623	63,073	63,073	63,468	66,610	64,681	54,283	33,242
Germany	21,345	21,345	21,345	19,327	14,021	5,690	0	0
Netherlands	450	450	450	450	450	0	0	0
Spain	7,524	7,524	7,524	7,599	7,341	7,341	7,341	3,219
Sweden	9,432	9,432	9,432	8,920	9,362	7,321	5,416	0
Switzerland	3,192	3,192	3,192	3,224	3,384	2,997	2,242	2,242
United Kingdom	12,968	12,498	12,498	10,994	6,959	3,649	1,259	1,259
Industrialized Asia	**43,491**	**43,491**	**43,245**	**43,891**	**49,398**	**48,561**	**41,582**	**35,814**
Japan	43,491	43,491	43,245	43,891	49,398	48,561	41,582	35,814
Total Industrialized	**280,839**	**278,726**	**278,657**	**281,057**	**278,874**	**259,923**	**224,757**	**185,168**
EE/FSU								
Eastern Europe	**10,292**	**10,680**	**11,592**	**10,981**	**10,659**	**10,659**	**11,309**	**8,360**
Bulgaria	3,538	3,538	3,538	2,749	2,020	2,020	2,020	2,020
Czech Republic	1,648	1,648	2,560	3,507	3,680	3,680	3,680	3,244
Hungary	1,755	1,755	1,755	1,773	1,860	1,860	1,860	930
Romania	655	655	655	662	694	694	1,344	1,344
Slovakia	2,020	2,408	2,408	1,608	1,688	1,688	1,688	823
Slovenia	676	676	676	683	717	717	717	0
Former Soviet Union	**34,704**	**33,779**	**34,729**	**34,049**	**32,351**	**25,748**	**18,805**	**8,924**
Armenia	376	376	376	0	0	0	0	0
Lithuania	2,370	2,370	2,370	1,185	0	0	0	0
Russia	19,843	19,843	20,793	21,562	22,504	16,685	12,763	7,917
Ukraine	12,115	11,190	11,190	11,302	9,847	9,063	6,042	1,007
Total EE/FSU	**44,996**	**44,459**	**46,321**	**45,030**	**43,010**	**36,408**	**30,115**	**17,284**

See notes at end of table.

Table E3. World Nuclear Generating Capacity by Region and Country, Low Growth Case, 1999-2025 (Continued)
(Megawatts)

Region/Country	History			Projections				
	1999	2000	2001	2005	2010	2015	2020	2025
Developing Countries								
Developing Asia	**21,861**	**22,767**	**22,969**	**30,063**	**36,315**	**42,905**	**45,533**	**46,012**
China	2,167	2,167	2,167	6,603	8,603	9,593	12,593	12,314
India	1,695	2,301	2,503	2,113	2,466	4,616	4,616	6,986
Pakistan	125	425	425	425	300	900	1,500	2,700
South Korea	12,990	12,990	12,990	15,989	17,057	19,907	20,216	21,300
Taiwan	4,884	4,884	4,884	4,933	7,889	7,889	6,609	2,712
Middle East	**0**	**0**	**0**	**915**	**915**	**915**	**2,111**	**2,111**
Iran	0	0	0	915	915	915	2,111	2,111
Africa	**1,800**	**1,800**	**1,800**	**1,818**	**1,908**	**1,908**	**1,908**	**0**
Egypt	0	0	0	0	0	0	0	1,000
South Africa	1,800	1,800	1,800	1,818	1,908	1,908	1,908	0
Central and South America	**1,561**	**2,836**	**2,836**	**2,836**	**2,501**	**2,501**	**2,504**	**2,504**
Argentina	935	935	935	935	600	600	0	0
Brazil	626	1,901	1,901	1,901	1,901	1,901	2,504	2,504
Total Developing	**25,466**	**27,403**	**27,605**	**35,632**	**41,639**	**48,229**	**52,056**	**50,627**
Total World	**349,233**	**350,588**	**352,583**	**361,718**	**363,523**	**344,560**	**306,928**	**253,080**

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 2002). **Projections:** Energy Information Administration (EIA), *Annual Energy Outlook 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table A9; and EIA, Office of Coal, Nuclear, Electric and Alternate Fuels, based on detailed assessments of country-specific nuclear power plants.

Appendix F

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 projections are provided for regions and selected countries. Projections are made for 14 individual countries, 9 of which—United States, Canada, Mexico, Japan, United Kingdom, France, Germany, Italy, and Netherlands—are part of the designation "industrialized countries." Individual country projections are also made for China, India, South Korea, Turkey, and Brazil, all of which are considered "developing countries." Beyond those individual countries, the rest of the world is divided into regions. Industrialized regions include North America (Canada, Mexico, and the United States), Western Europe (United Kingdom, France, Germany, Italy, Netherlands, and Other Europe), and Pacific (Japan and Australia / New Zealand). Developing regions include developing Asia (China, India, South Korea, and Other Asia), Middle East (Turkey and Other Middle East), Africa, and Central and South America (Brazil and Other Central and South America). The "transitional economies," consisting of the countries in Eastern Europe (EE) and the former Soviet Union (FSU), are considered as a separate country grouping, neither industrialized nor developing.

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 SAGE is forthcoming in a three-volume set. The first volume will provide a general understanding of the model's design, theoretical basis, necessary user-defined assumptions, and output. It will also list the software necessary to develop and analyze the results of SAGE-based policy and energy market scenarios and provide vendor contact information. The second volume, a Reference Guide, will explain each equation in detail, and a third volume will serve as a User's Guide for those actively developing SAGE-based scenario analyses. The documentation will be available on EIA's web site in the summer of 2003. Also available for downloading at that time will be the regional assumptions used to develop the *IEO2003* projections. The format of the assumptions will follow the instructions appearing in the User's Guide.