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Preface

This report presents international energy projections through 2020, prepared by the Energy Information Administration, including outlooks for major energy fuels and issues related to electricity, transportation, and the environment.

The *International Energy Outlook 2002* (*IEO2002*) presents an assessment by the Energy Information Administration (EIA) of the outlook for international energy markets through 2020. The report is an extension of the EIA's *Annual Energy Outlook 2002* (*AEO2002*), which was prepared using the National Energy Modeling System (NEMS). U.S. projections appearing in the *IEO2002* are consistent with those published in the *AEO2002*. *IEO2002* is provided as a statistical service to energy managers and analysts, both in government and in the private sector. The projections are used by international agencies, Federal and State governments, trade associations, and other planners and decisionmakers. They are published pursuant to the Department of Energy Organization Act of 1977 (Public Law 95-91), Section 205(c). The *IEO2002* projections are based on U.S. and foreign government policies in effect on October 1, 2001.

Projections in *IEO2002* are displayed according to six basic country groupings (Figure 1). The industrialized region includes projections for nine individual countries—the United States, Canada, Mexico, Japan, France, Germany, Italy, the Netherlands, and the United Kingdom—plus the subgroups Other Europe and Australasia, which is defined as Australia, New Zealand, and the U.S. Territories (Guam, Puerto Rico, and the U.S. Virgin Islands). 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 EE/FSU nations are further separated into Annex I and non-Annex I member countries participating in the Kyoto Climate Change Protocol on Greenhouse Gas Emissions. These groupings are used to assess the potential role of Annex I EE/FSU countries in reaching the Annex I emissions targets of the Kyoto Climate Change Protocol.

The report begins with a review of world trends in energy demand. The historical time frame begins with data from 1970 and extends to 1999, providing readers with a 29-year historical view of energy demand. The *IEO2002* projections cover a 21-year period.

High economic growth and low economic growth cases were developed to depict a set of alternative growth paths for the energy forecast. The two 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 issues, including global carbon emissions, is reviewed. Comparisons of the *IEO2002* projections with other available international energy forecasts are included in the first chapter.

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

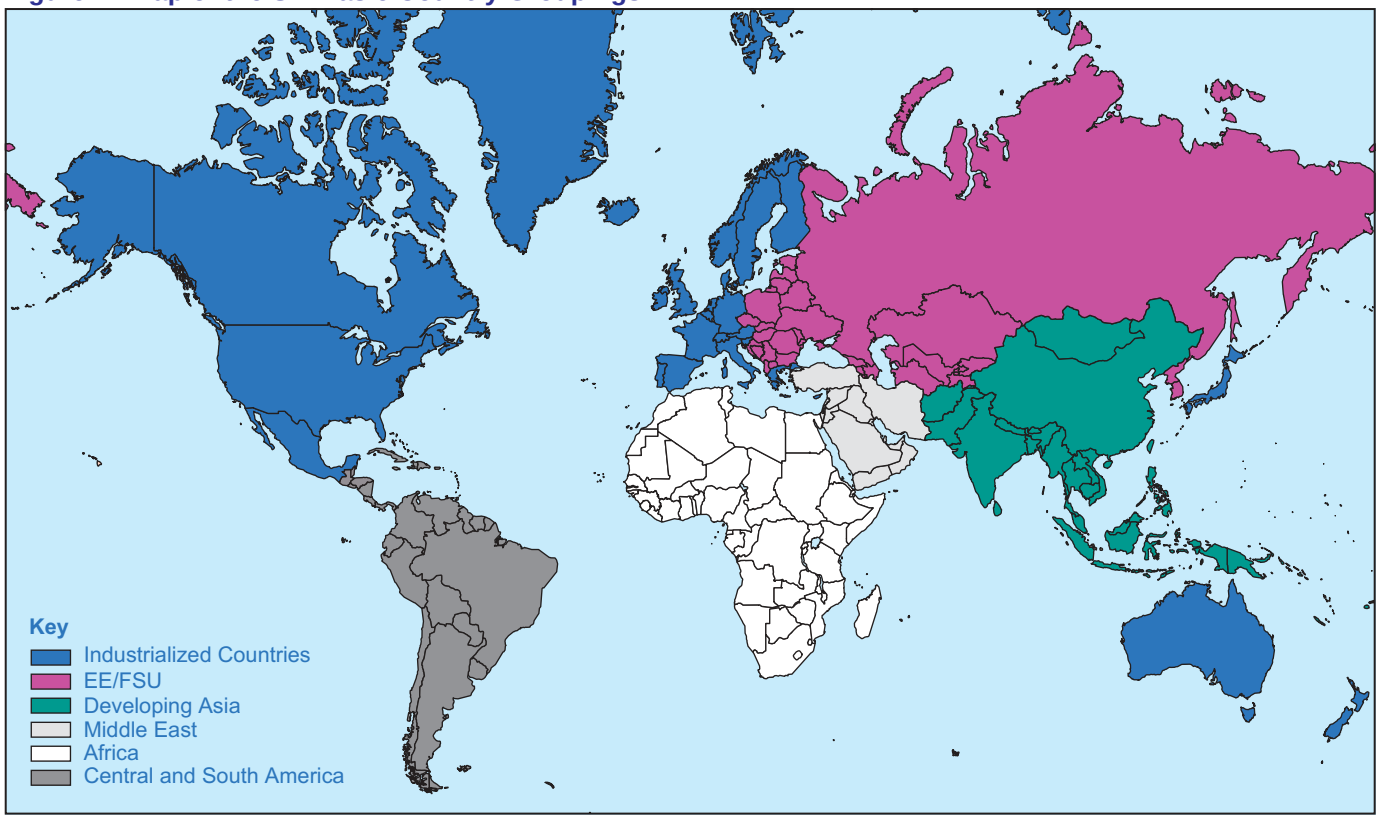
Appendix A contains summary tables of the *IEO2002* reference case projections for world energy consumption, gross domestic product (GDP), energy consumption by fuel, electricity consumption, carbon emissions, nuclear generating capacity, energy consumption measured in oil-equivalent units, and regional 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 World Energy Projection System (WEPS) model, 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 *consumption* projections for the reference case were derived from the International Nuclear Model, PC Version (PC-INM). Nuclear *capacity* projections for the reference case were based on analysts' knowledge of the nuclear programs in different countries.

Appendix B and C present projections for the high and low economic growth cases, respectively. Nuclear *capacity* projections for the high and low growth cases were based on analysts' knowledge of nuclear programs. Nuclear *consumption* projections for both cases were derived from WEPS. Appendix D contains summary tables of projections for world oil production capacity and oil production in the reference case and two alternative cases: high oil price and low oil price. The projections were derived from WEPS and from the U.S. Geological Survey. Appendix E presents regional forecasts of transportation energy use in the reference case, derived from the WEPS model. Appendix F describes the WEPS model. Appendix G presents comparisons of historical data with the projections published in previous *IEO*s.

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

- **Industrialized Countries** (the industrialized countries contain 18 percent of the 2001 world population): Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and the United States.
- **Eastern Europe and the Former Soviet Union (EE/FSU)** (7 percent of the 2001 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** (55 percent of the 2001 world population): Afghanistan, Bangladesh, Bhutan, Brunei, Cambodia (Kampuchea), China, Fiji, French Polynesia, 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 2001 world population): Bahrain, Cyprus, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, Turkey, the United Arab Emirates, and Yemen.

Figure 1. Map of the Six Basic Country Groupings



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

- **Africa** (10 percent of the 2001 world population): Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo (Brazzaville), Congo (Kinshasa), Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Ivory Coast, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Reunion, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, St. Helena, Sudan, Swaziland, Tanzania, Togo, Tunisia, Uganda, Western Sahara, Zambia, and Zimbabwe.

- **Central and South America** (6 percent of the 2001 world population): Antarctica, Antigua and Barbuda, Argentina, Aruba, Bahama Islands, Barbados, Belize, Bolivia, Brazil, British Virgin Islands, Cayman Islands, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, Falkland Islands, French Guiana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Montserrat, Netherlands Antilles, Nicaragua, Panama Republic, Paraguay, Peru, St. Kitts-Nevis, St. Lucia, St. Vincent / Grenadines, Suriname, Trinidad and Tobago, Turks and Caicos Islands, Uruguay, 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.

- **Mercosur Trading Block:** Argentina, Brazil, Paraguay, and Uruguay. Chile and Bolivia are Associate Members.

- **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 *IEO2002* Projections

The projections in *IEO2002* are not statements of what will happen, but what might happen given the specific assumptions and methodologies used. These projections provide an objective, policy-neutral reference case that can be used to analyze international energy markets. As a policy-neutral data and analysis organization, EIA does not propose, advocate, or speculate on future legislative and regulatory changes. The projections are based on current U.S. and foreign government policies. Assuming current policies, even knowing that changes will occur, will naturally result in projections that differ from the final data.

Models are abstractions of energy production and consumption activities, regulatory activities, and producer and consumer behavior. The forecasts are highly dependent on the data, analytical methodologies, model structures, and specific assumptions used in their development. Trends depicted in the analysis are indicative of tendencies in the real world rather than representations of specific real-world outcomes. Even where trends are stable and well understood, the projections are subject to uncertainty. Many events that shape energy markets are random and cannot be anticipated, and assumptions concerning future technology characteristics, demographics, and resource availability cannot be known with 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 60 percent from 1999 to 2020. Much of the growth in worldwide energy use is expected in the developing world in the IEO2002 reference case forecast.

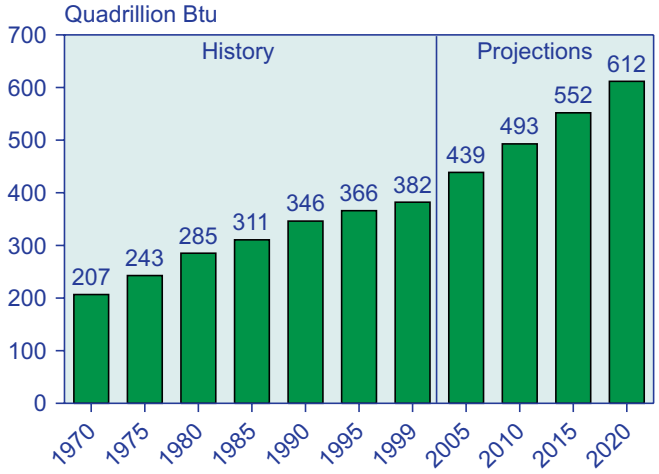
In the reference case projections for the *International Energy Outlook 2002* (*IEO2002*), world energy consumption is projected to increase by 60 percent over a 21-year forecast horizon, from 1999 to 2020. Worldwide energy use grows from 382 quadrillion British thermal units (Btu) in 1999 to 612 quadrillion Btu in 2020 (Figure 2). Energy markets were influenced by a host of developments in 2001, including high world oil prices that persisted from 2000 into the first part of 2001 and then weakened substantially in the third quarter of the year; a global economic slowdown led by a mild recession in the United States; and the aftermath of the terrorist attacks on the United States on September 11, 2001.

Despite the events of the past year, much of the growth in worldwide energy use is still expected in the developing world, as it has been in past editions of this outlook (Figure 3). In particular, energy demand in developing Asia and Central and South America is projected to more than double between 1999 and 2020. Both of these regions are expected to sustain energy demand growth of about 4 percent annually throughout the forecast, accounting for about half of the total projected increment in world energy consumption and 83 percent of the increment for the developing world alone.

High world oil prices carried into 2001 from the previous year, and for the first half of the year they remained within—and, during day trading, occasionally spiked above—the $22 to $28 per barrel price band that the Organization of Petroleum Exporting Countries (OPEC) has defined as its preferred range. Although prices spiked initially after the September 11 terrorist attacks launched on the United States, oil demand weakened substantially in the weeks and months that followed the attacks, and OPEC found it difficult to hold prices much above the $22 per barrel mark. Even after three production quota cuts amounting to 3.5 million barrels per day were made in 2001, prices did not strengthen. At the end of 2001, OPEC entered into a protracted negotiation with key non-OPEC producers aimed at reducing oil exports enough to shore up the world market price. OPEC members (excluding Iraq) agreed to cut 1.5 million barrels of production, and non-OPEC producers Angola, Norway, Mexico, Oman, and Russia agreed to take a combined 462,500 barrels per day out of the export market beginning in January 2002.

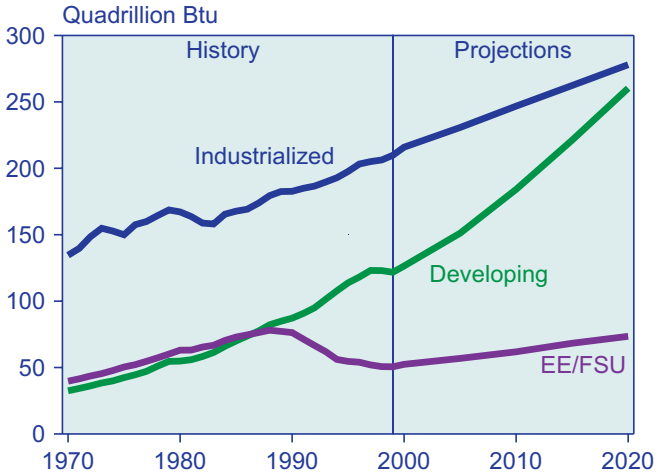
The U.S. refiner acquisition cost of imported crude oil fell from $27.72 per barrel in 2000 to an estimated $22.05 per barrel in 2001 (nominal dollars). The *IEO2002*

Figure 2. World Energy Consumption, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

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



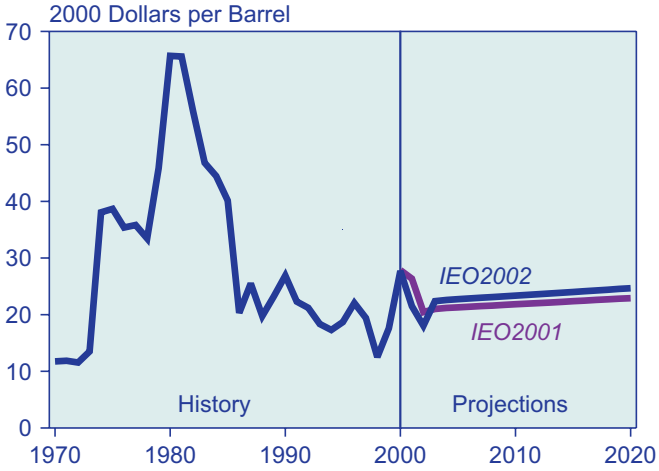
Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

reference case expects world oil prices to moderate in 2002 and return to the price trajectory anticipated in last year's outlook for the mid-term. World oil prices are expected to reach $25 per barrel in 2000 dollars ($42 per barrel in nominal dollars) at the end of the projection period. This year's projection for world oil prices is slightly higher than last year's projection (Figure 4), reflecting the successes OPEC had in managing oil production cutbacks to raise oil prices in 2000, along with a more optimistic mid-term outlook for demand in the world's developing countries.

Outlook for World Energy Demand

Much of the industrialized world experienced economic slowdown in 2001, led by what is estimated to have been a recession in the United States since March 2001. The lowered economic activity in the industrialized world will have short-term impacts on the rest of the world as demand for products and services from developing countries slows in response. Lowered demand for computer equipment has already nudged high-tech exporters South Korea and Taiwan into recession. The mid-term forecast assumes that the recession will not be protracted in the United States, and that gross domestic product (GDP) growth and energy demand growth will rebound and will largely resume the trend projected in last year's outlook. The *IEO2002* reference case expects that energy consumption in the industrialized world will grow by 1.3 percent per year between 1999 and 2020, slightly higher than the 1.2 percent per year projected in last year's report.

Figure 4. Comparison of 2001 and 2002 World Oil Price Projections



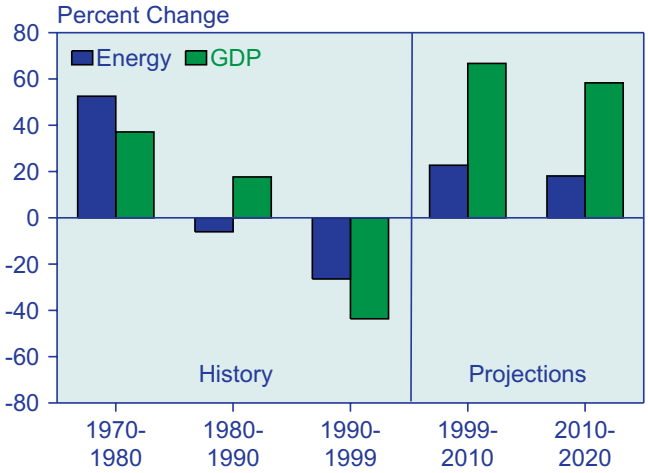
Sources: **History:** Energy Information Administration (EIA), *Annual Energy Review 2000*, DOE/EIA-0384(2000) (Washington, DC, July 2001). ***IEO2001:*** EIA, *International Energy Outlook 2001*, DOE/EIA-0484(2001) (Washington, DC, March 2001). ***IEO2002:*** 1999-2002—EIA, *Short-Term Energy Outlook*, on-line version (February 7, 2002), web site www.eia.doe.gov/emeu/steo/pub/contents.html. 2003-2020—EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001).

One of the few bright spots among the world's regional economies in 2001 was the former Soviet Union (FSU), where GDP registered a second year of positive growth for every nation in the region. High oil prices and a devalued ruble helped Russia—the region's largest economy—post strong economic gains by boosting performance in the country's industrial sector. As the ruble regained value in 2001, the manufacturing sector slowed somewhat (as imported goods once again could compete with domestic goods), but high world oil prices in the first three quarters of the year helped Russia return to a GDP growth rate of 5.3 percent.

Ukraine, the second largest economy in the FSU, also reported positive economic growth in 2001—only its second year of positive GDP since the dissolution of the Soviet Union in 1989. Ukraine is a net importer of oil, and the high world oil prices did not benefit its economy. Instead, fiscal reform and strong growth in industrial output, construction activity, agriculture, and exports, along with fast-paced growth in domestic consumption and investment, helped to fuel Ukraine's economic growth. The improving economic outlook for Russia and the rest of the FSU suggests a more sustained period of growth for the region and is expected to result in energy demand growth for the region of 1.8 percent per year between 1999 and 2020, reaching 57 quadrillion Btu at the end of the forecast (Figure 5).

Worldwide, oil consumption rose by less than 100,000 barrels per day in 2001, divided evenly among the industrialized (mainly Western Europe) and developing (mainly Central and South America) nations. Demand is expected to begin to recover in 2002 as the world economies begin to recover from the slowdown in 2001, and

Figure 5. Percent Change in Energy Consumption and GDP in the Former Soviet Union



Sources: DRI-WEFA World Economic Outlook 2001, Third Quarter; Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001); and EIA, World Energy Projection System (2002).

global oil demand is projected to expand by about 600,000 barrels per day in 2002. The increases in worldwide oil use projected in the reference case would require an increment of almost 44 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, with the offshore Atlantic Basin emerging as a major future source of oil production in both Latin America and Africa.

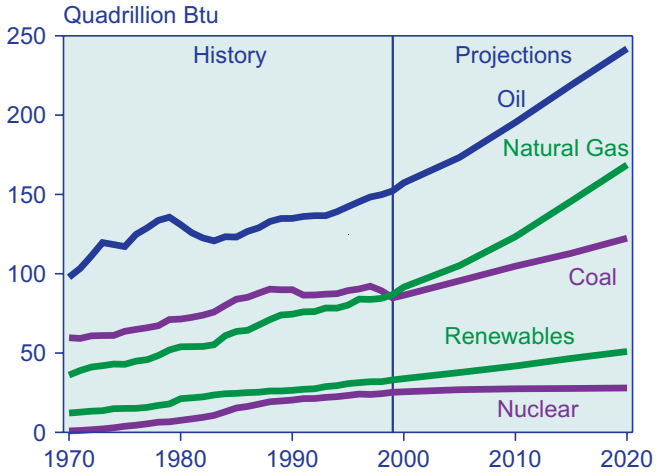
World Energy Consumption by Energy Source

Throughout the past several decades, oil has been the world's dominant source of primary energy consumption, and it is expected to remain in that position with a 40-percent share of total energy consumption over the 1999-2020 period (Figure 6). The oil share of the world energy pie does not increase in the forecast because countries in many parts of the world are expected to switch from oil to natural gas and other fuels, particularly for electricity generation. Its share of total energy consumption is expected to remain constant because of its predominance in the transportation sector, where energy use is projected to grow robustly over the next two decades. World oil consumption is projected to increase by 2.2 percent annually over the 21-year projection period, from 75 million barrels per day in 1999 to 119 million barrels per day in 2020.

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 1999, developing nations consumed 58 percent of the amount of oil consumed in the industrialized world, but by 2020 they are expected to consume almost 90 percent as much oil as the industrialized world. The increase in oil use in the industrialized world is expected to occur predominantly in the transportation sector, where there are presently few economically competitive alternatives to oil. In the developing world, oil demand is projected to grow in all end-use sectors. As the energy infrastructures of emerging economies improve, people are turning from traditional fuels like wood burning for heating and cooking to electricity, and additional petrochemical feedstocks are being used for industry.

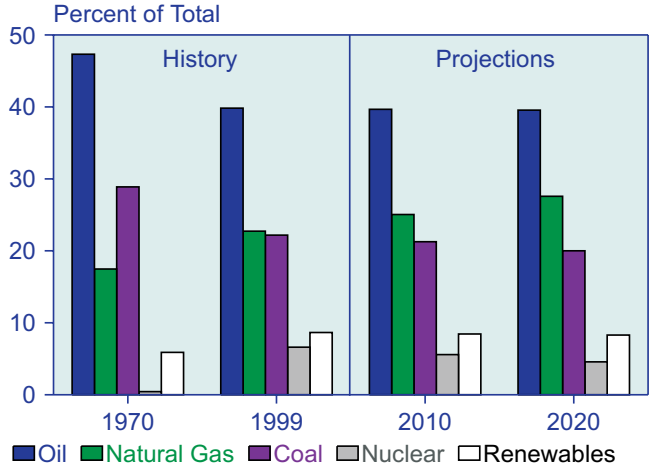
The fastest growing source of energy consumption in the *IEO2002* reference case is projected to be natural gas. Over the 1999-2020 forecast period, gas use is projected to nearly double in the reference case, reaching 162 trillion cubic feet in 2020. Natural gas use surpassed coal use (on a Btu basis) for the first time in 1999, and by 2020 it is expected to exceed coal use by 38 percent (Figure 7). The natural gas share of total energy consumption is projected to increase from 23 percent in 1999 to 28 percent in 2020, and natural gas is expected to account for the largest increment in electricity generation (increasing by 33 quadrillion Btu and accounting for 43 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

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



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

Figure 7. World Energy Consumption Shares by Fuel Type, 1970, 1999, 2010, and 2020



Sources: **1970 and 1999:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **2010 and 2020:** EIA, World Energy Projection System (2002).

power plants. Gas use is increasing for a number of additional reasons, including price, environmental concerns, fuel diversification and/or energy security issues, market deregulation (for both gas and electricity), and overall economic growth.

In the industrialized world, natural gas is expected to make a greater contribution to incremental energy consumption among the major fuels, increasingly becoming the choice for new power generation because of its environmental and economic advantages. In the developing countries, increments in gas use are expected to supply both power generation and industrial uses. The *IEO2002* reference case projects particularly robust growth in natural gas use in the developing world, averaging 5.3 percent per year between 1999 and 2020, reflecting the growing popularity of the fuel, as well as the expectation that the relatively immature gas markets of emerging countries will develop quickly over 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 1.7 percent per year through 2020, suggests that coal will account for a shrinking share of world energy consumption. In 1999, coal provided 22 percent of world primary energy consumption, down from 27 percent in 1985. In the *IEO2002* reference case, the coal share of total energy consumption is projected to fall to 20 percent by 2020. 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 83 percent of the total expected increase in coal use worldwide (on a Btu basis).

Coal consumption is heavily concentrated in the electricity generation sector. Almost 65 percent of the world's coal use is for electricity generation, and power generation accounts for virtually all the projected growth in coal consumption worldwide. 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.

Although past editions of this report have projected declines in nuclear electricity consumption, higher capacity utilization and fewer expected retirements of existing plants have resulted in a revision to the expectations for a decline in consumption. Extensions of operating licenses (or the equivalent) for nuclear power plants are expected to be requested and granted among the countries of the industrialized world. With more of the existing nuclear power plants expected to remain in operation, the projected decline in nuclear generation is slowed. In the *IEO2002* reference case, world nuclear capacity is projected to rise from 350 gigawatts in 2000 to 363 gigawatts in 2010 before falling 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 4.7 percent per year between 1999 and 2020. In particular, developing Asia is expected to see the greatest expansion in new nuclear generating capacity. The nations of developing Asia account for half the reactors currently under construction worldwide, including eight in China, four in South Korea, two in India, and two in Taiwan.

Renewable energy use is expected to increase by 53 percent between 1999 and 2020, but its current 9-percent share of total energy consumption is projected to drop slightly to 8 percent by 2020. Over the forecast horizon, growth in renewable energy resources is expected to continue to be constrained by relatively moderate fossil fuel prices. Renewable energy consumption is expected to be driven by new, large-scale hydroelectric projects, particularly in China, India, Malaysia, and other developing Asian countries. In 2001, construction on megahydro projects like China's 18,200-megawatt Three Gorges Dam and Malaysia's 2,400-megawatt Bakun continued amidst criticism of their environmental impacts and concerns about the welfare of the people being relocated to accommodate the projects.

The world's use of electricity is projected to increase by two-thirds over the forecast horizon, from 13 trillion kilowatthours in 1999 to 22 trillion kilowatthours in 2020. The strongest growth rates in electricity consumption are projected for developing Asia, where electricity consumption is expected to grow by 4.5 percent per year as robust economic growth increases the demand for electricity to run newly purchased air conditioners, refrigerators, stoves, space heaters, and water heaters. In the industrialized world, electricity consumption is expected to grow at a more modest pace. Slower population and economic growth, along with the market saturation of certain electronic appliances (such as air conditioners) and efficiency gains from electrical appliances help to explain the expected slower growth of electricity use in the industrialized nations, although growing computer usage and the introduction of new electronic devices could moderate that trend somewhat in the future.

There have been two important developments in the electricity sector in recent years that may affect the way the industry works in the future. The first is the

increasing role of foreign direct investment in the developing regions of the world. Greater access to foreign investment in the electricity sector has allowed developing nations to construct the infrastructure needed for substantial increases in access to electricity, a particular problem for many developing nations. A second important component of the electric industry's evolution over the past several years is electricity reform. Many developing countries have implemented reforms to the rules governing electricity generation and distribution in an effort to secure the foreign direct investment they need to modernize and improve the electricity infrastructure. In industrialized countries, many nations have undertaken electricity reforms to introduce greater competition in domestic markets in an effort to reduce the costs of electricity to consumers.

Outlook for Transportation Energy Use

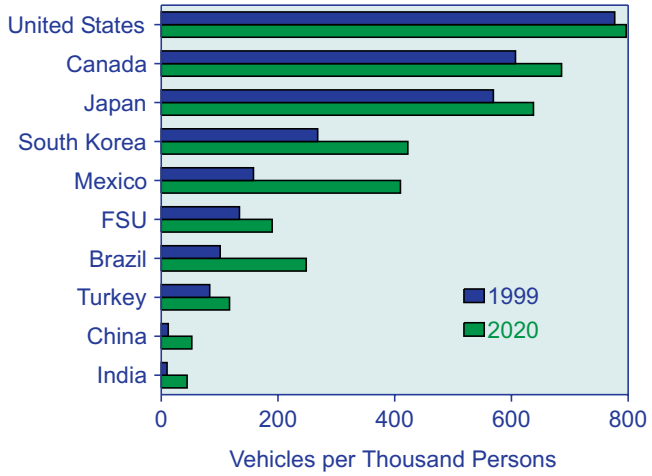
The past year saw a reversal of the high prices and tight markets that characterized the energy industry in 2000. Transportation demand growth in 2001 is likely to be the lowest in several years, with slowing economic growth moderating growth in world oil demand even before the September 11 terrorist attacks on the United States. Despite the recent pressure on transportation fuels from oil prices that hit 10-year highs in 2000, transportation energy use is expected to continue robust growth over the next two decades, especially in the developing world, where relatively immature transportation infrastructures are expected to grow rapidly as national and regional economies expand. In the *IEO2002* reference case, energy use for transportation is projected to increase by 3.8 percent per year in the developing world, compared with average annual increases of 1.7 percent for the industrialized countries, where transportation systems are largely established and motorization levels (per capita vehicle ownership) are, in many nations, expected to reach saturation levels over the 21-year forecast horizon.

In urban centers of the developing world, car ownership is often seen as one of the first symbols of emerging prosperity. Per capita motorization in much of the developing world is projected to more than double between 1999 and 2020, although population growth is expected to keep motorization levels low relative to those in the industrialized world. For example, the U.S. per capita motorization level in 2020 is projected at 797 vehicles per thousand persons, but in China—where motorization is expected to grow fivefold over the forecast horizon—the projected motorization level in 2020 is only 52 vehicles per thousand persons (Figure 8).

Carbon Dioxide Emissions

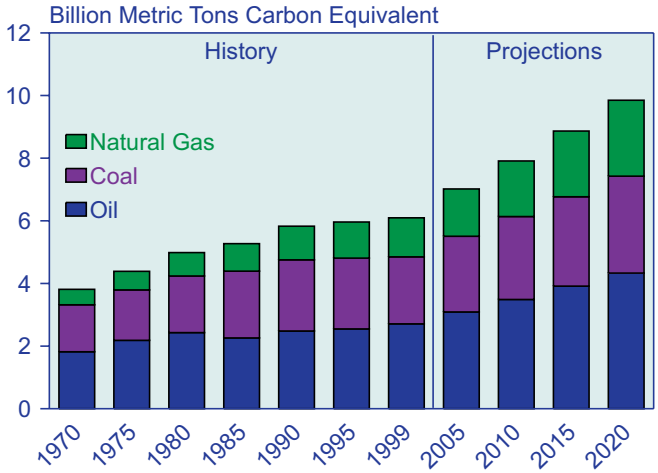
Because estimates indicate that approximately 80 percent of all human-caused carbon dioxide emissions currently come from fossil fuel combustion, world energy use has emerged at the center of the climate change debate. In the *IEO2002* reference case, world carbon dioxide emissions are projected to rise from 6.1 billion metric tons carbon equivalent in 1999 to 7.9 billion metric tons per year in 2010 and to 9.9 billion metric tons in 2020 (Figure 9). Much of the projected increase in carbon dioxide emissions is expected to occur in the developing world, where emerging economies are expected to produce the largest increases in energy consumption. Developing countries alone account for 77 percent of the projected increment in carbon dioxide emissions between 1990 and 2010 and 72 percent between 1990 and 2020. Continued heavy reliance on coal and other fossil

Figure 8. Motorization Levels in Selected Countries, 1999 and 2020



Sources: **1999:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **2020:** EIA, World Energy Projection System (2002).

Figure 9. World Carbon Dioxide Emissions by Fossil Fuel, 1970-2020



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

fuels, as projected for the developing countries, would ensure that even if the industrialized world undertook efforts to reduce carbon dioxide emissions, worldwide carbon dioxide emissions would still grow substantially over the forecast horizon.

Energy Intensity

The *IEO2002* projections, like all forecasts, are accompanied by a measure of uncertainty. One way to quantify the uncertainty is to consider the relationship between energy consumption and growth in gross domestic product (that is, energy intensity) 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.

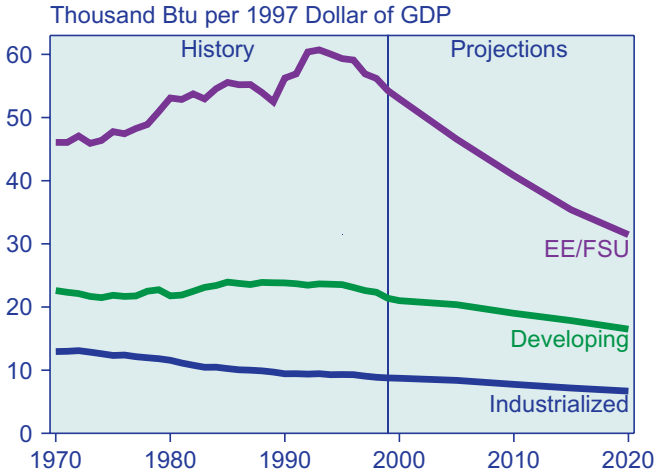
In the *IEO2002* forecast, energy intensity in the industrialized countries is expected to improve (decrease) by 1.3 percent per year between 1999 and 2020, about the same rate of improvement observed in the region between 1970 and 1999. Energy intensity is also projected to improve in the developing countries—by 1.2 percent per year—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, energy intensity is expected to improve in the EE/FSU region 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

Carbon intensity—the amount of carbon dioxide emitted per dollar of GDP—is also projected to improve throughout the world over the next two decades (Figure 11). The most rapid improvements are, for the most part, projected for the transitional economies of the 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.

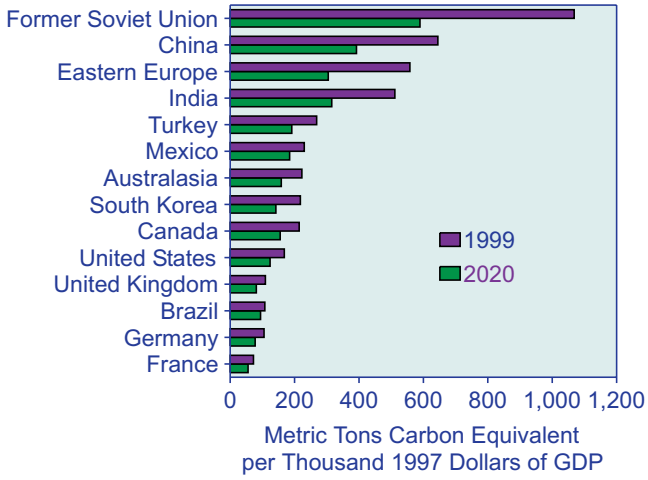
In developing Asia, China and India are also expected to see fairly rapid improvements in carbon intensity over the projection period, primarily as a result of rapid economic growth rather than a switch to less carbon-intensive fuels. Both China and India are expected to continue their heavy dependence on fossil fuels, especially coal, in the *IEO2002* reference case forecast, but their combined annual GDP growth is projected to average 6.6 percent, compared with an expected 4.4-percent annual rate of increase in fossil fuel use from 1999 to 2020.

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



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

Figure 11. Carbon Intensity in Selected Countries and Regions, 1999 and 2020



Sources: **1999:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **2020:** EIA, World Energy Projection System (2002).

World Energy Consumption

The IEO2002 projections indicate continued growth in world energy use, including large increases for the developing economies of Asia and South America. Energy resources are thought to be adequate to support the growth expected through 2020.

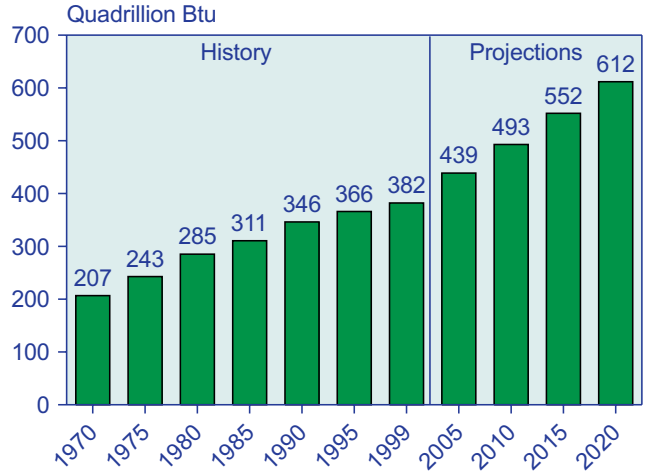
The *International Energy Outlook 2002* (*IEO2002*) presents the Energy Information Administration (EIA) outlook for world energy markets to 2020. Current trends in world energy markets are discussed in this chapter, followed by a presentation of the *IEO2002* projections for energy consumption by primary energy source and for carbon emissions by fossil fuel. Uncertainty in the forecast is highlighted by an examination of alternative assumptions about economic growth and their impacts on the *IEO2002* projections and how future energy intensity trends could influence the reference case projections. The chapter ends with a comparison of the *IEO2002* projections with forecasts available from other organizations.

Current Trends in World Energy Demand

Between 1999 and 2020, total world energy use is projected to grow from 382 quadrillion British thermal units (Btu) to 612 quadrillion Btu (Figure 12 and Table 1)—a 60-percent increase—in the *IEO2002* reference case projection. Energy markets in 2001 were affected by a host of developments and events, including high world oil prices that continued from 2000 into the first half of the year and then weakened substantially toward the end of the year; a global economic slowdown led by the United States; and the aftermath of the terrorist attacks on the United States on September 11, 2001.

For much of 2001, world oil prices remained in the news, with prices within or slightly above the price range of $22 to $28 per barrel that the Organization of Petroleum Exporting Countries (OPEC) considers optimal (Figure 13). After September 11, oil prices initially spiked, but a substantial lowering of demand in the weeks and months that followed made it difficult for OPEC to hold prices much above the $22 per barrel level [***1***]. An OPEC meeting on September 26-27 did not result in an anticipated oil production cut to shore up prices, which were beginning to fall even before the terrorist attacks.

Figure 12. World Energy Consumption, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

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

Region	Energy Consumption (Quadrillion Btu)				Carbon Dioxide Emissions (Million Metric Tons Carbon Equivalent)			
	1990	1999	2010	2020	1990	1999	2010	2020
Industrialized Countries	**182.7**	**209.7**	**246.6**	**277.8**	**2,849**	**3,129**	**3,692**	**4,169**
EE/FSU	**76.3**	**50.4**	**61.8**	**73.4**	**1,337**	**810**	**978**	**1,139**
Developing Countries	**87.2**	**121.8**	**184.1**	**260.3**	**1,641**	**2,158**	**3,241**	**4,542**
Asia	51.0	70.9	113.9	162.2	1,053	1,361	2,139	3,017
Middle East	13.1	19.3	26.3	34.8	231	330	439	566
Africa	9.3	11.8	15.7	20.3	179	218	287	365
Central and South America	13.7	19.8	28.3	43.1	178	249	377	595
Total World	**346.2**	**381.9**	**492.6**	**611.5**	**5,827**	**6,097**	**7,910**	**9,850**

Sources: **1990 and 1999:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

The organization was concerned about maintaining stable oil markets after the attacks.

OPEC experienced some difficulties in trying to maintain its desired price band both before and after the September attacks. The slowing U.S. economy had already reduced the demand for oil, and the cartel reduced oil production quotas by a combined 3.5 million barrels per day in three separate instances before the terrorist attacks [***2***]. In mid-November 2001, the OPEC member nations met again to discuss ways to boost sagging oil prices that had fallen to as low as $18 per barrel and had dipped even lower in day trading. OPEC announced it would cut production by another 1.5 million barrels per day, beginning in January 2002, but only on condition that key non-OPEC oil suppliers, Mexico, Oman, Russia, and Norway, would also cut production. Angola and Kazakhstan also indicated a willingness to consider cutting exports [***3***]. OPEC wanted non-OPEC suppliers to remove a combined 500,000 barrels per day from the market.

Russia proved to be the single holdout against OPEC's demands for a production cutback, initially offering to cut only 50,000 barrels per day in production [***4***]. OPEC had hoped for a Russian cut of between 100,000 to 150,000 barrels per day. Some analysts thought there could be a price war in early 2002, with Saudi Arabia and Russia—the two largest oil producers in the world—vying for market share. Finally, on December 5, Russia announced that it would cut its oil exports by some 5 percent, or the 150,000 barrels per day that OPEC had requested, beginning in January 2002 [***5***].

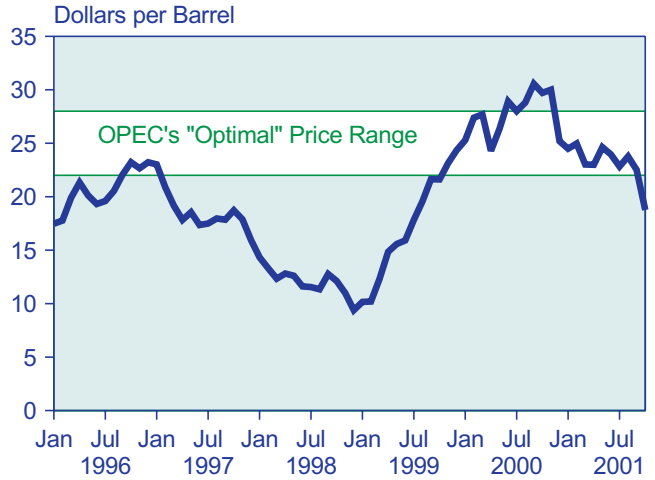
The degree of compliance among the OPEC and non-OPEC members who struck the December 2001 agreement remained uncertain as *IEO2002* went to print. The OPEC member countries (not including Iraq) succeeded in reducing their oil production by an estimated 1 million barrels per day in January 2002 [***6***]. Non-OPEC members had mixed success, however, in meeting their commitments to reduce oil production. The future for supply cuts is also uncertain. Norway has announced that it will continue its pledged supply cut at least until the end of June 2002, but Russia has not yet decided whether to extend its pledge to cut 150,000 barrels per day for a second quarter [***7***]. OPEC has indicated that its cuts may remain in place until 2003 if demand and prices remain weak.

With the terrorist attacks and the ensuing war launched in Afghanistan against the Al Qaeda terrorist network and the ruling Taliban regime, the short-term outlook for world economic and energy growth is fraught with even more uncertainty than normal. The mid-term outlook will also be affected by developments in the American-led anti-terrorist actions, an outlook that is difficult to assess in early 2002.

Nevertheless, *IEO2002* expects that the regional trends underlying the reference case in past editions of this report will not be substantially altered. The *IEO2002* reference case forecast still shows the fastest pace of growth in energy demand over the next two decades in the developing world, with developing Asia and Central and South America leading the way (Figure 14) as the economies in the two regions continue to develop and their consuming patterns increasingly come to resemble those of the industrialized world.

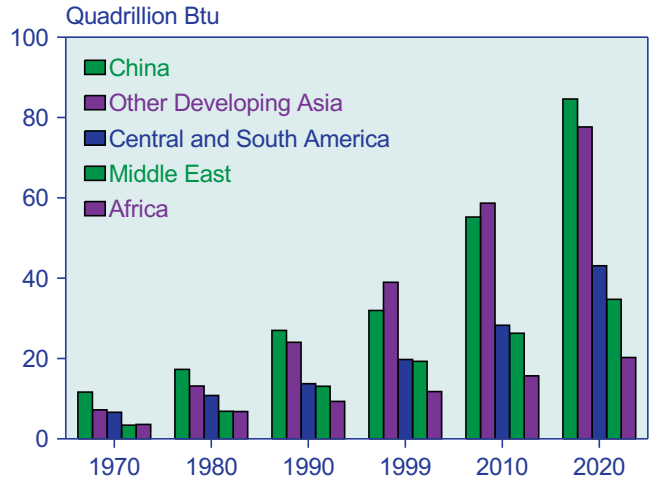
Developing countries as a whole are projected to account for 60 percent of the increment in total energy

Figure 13. Refiner Acquisition Cost of Imported Crude Oil, 1996-2001



Source: Energy Information Administration, *Monthly Energy Review*, DOE/EIA-0035(2000/01) (Washington, DC, January 2002).

Figure 14. Energy Consumption in the Developing World by Region, 1970-2020



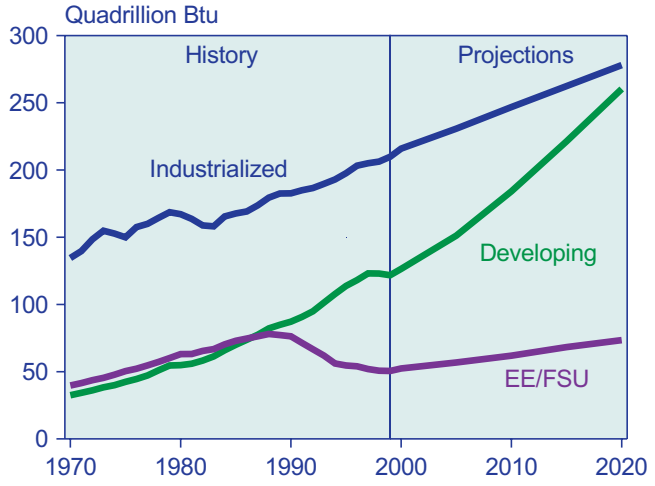
Sources: **1995-1999:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

use over the projection period, compared with the industrialized world's 30 percent (Figure 15). The emerging, transitional economies of Eastern Europe and the former Soviet Union (EE/FSU) account for the remainder.

Even before the events of September 11, the U.S. economy was showing signs of slipping, and many analysts believe the attacks in September virtually ensured that the country would be pushed into recession. In fact, the National Bureau of Economic Research declared in late November that a recession had begun in the United States as early as March 2001 [***8***]. Recession in the United States clearly has implications for international markets and, in turn, the demand for energy worldwide. Slowing markets in the United States mean a lowered demand for imports. The technology sector, spurred by a spate of computer upgrades because of Y2K-related fears in 1999, had slowed dramatically by 2001, resulting in slower economic growth for many Asian, technology-exporting countries, such as South Korea and Taiwan, which provide much of the computer equipment for the United States and other parts of the industrialized world [***9***].

The negative impact of the slowing U.S. economy on the markets of the developing world is expected to be made even worse because of the persistent Japanese recession and a slowing of the economies of Western Europe. With virtually all of the industrialized world slowing, or already in full recession, it will be difficult for the developing world to resist an economic turndown as well. Japan's economy was stagnant or in decline for much of 2001, and many analysts feel that the country is in yet another of a series of recessions that have plagued it for the past several years. Deflation continues to be problematic for Japan, as it has been since 1996, and consumers are reluctant to spend while the true value of their assumed debt continues to expand [***10***]. Thus far, Prime Minister Koizumi's efforts to shift government fiscal policy away from public works projects and toward economic reforms have not been successful.

Figure 15. Energy Consumption by Region, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

The Western European economies also began to show signs of recession or of economic slowdown in 2001. The European Central Bank (ECB) resisted cutting interest rates for the first quarter of 2001, but as the slowing economic performance became clear, the Governing Council agreed to cut interest rates by a total of 150 basis points between May and November in four separate instances. Two of the cuts were made after September 11, and the ECB Governing Council stated that its cut on September 17 was being made because the terrorist acts on the United States would be likely to "weigh adversely on confidence in the euro arena, reducing the short-term outlook for domestic growth" and to increase inflationary risks [***11***].

In Germany, Western Europe's largest economy, gross domestic product (GDP) growth fell to 0.8 percent in 2001, from 3.2 percent in 2000. Even before the September 11 terrorist attacks, the German economy showed signs of weakening, with year-to-year growth slowing from 1.8 percent in the first quarter of 2001 to 0.6 percent in the second quarter and 0.3 percent in the third [***12***]. Analysts speculated that the country would soon be in a recession. Tax cuts in 2001 helped to soften the impact of Germany's slowing economy in 2001, and the government is considering moving up the time frame for implementing further cuts originally scheduled for the period 2003 to 2005, in an attempt to stimulate economic recovery.

Other countries in Western Europe were also showing signs of weakening. Tax cuts helped to boost consumer spending in France in the first part of 2001, but weakening manufacturing output related to lowered export demand after the terrorist attacks in the United States is expected to make it difficult for France to maintain its pace of economic growth into 2002 [***13***]. Modest growth was reported in Italy and the United Kingdom, but export growth slowed substantially after September in both countries [***14***].

Developing Asia (outside of China and India) is particularly vulnerable to fluctuations in the economies of the industrialized world, because many Asian countries largely depend on revenues from exports to industrialized countries. In particular, the United States is the largest export market for most Asian countries, and the U.S. recession has already had adverse impacts on the Asian markets. Singapore and Taiwan have suffered income contractions, and Hong Kong and Malaysia are near

recession, with South Korea, Thailand, and Indonesia reporting slowing economic growth [***15***].

Exports from the developing Asian countries have uniformly declined. The demand for electronic technologies has not rebounded from the declines in 2000, which has hurt the economies of technology producers South Korea, Taiwan, Singapore, and Malaysia, resulting in a 20-percent decline in exports at the end of 2001. Even China and Indonesia—countries that are less dependent on technology-oriented exports—have suffered from the global economic slowdown in 2001. China's exports grew by 4 percent in the third quarter of 2001, compared with 25 percent during the same period in 2000. In Indonesia, exports declined by 10 percent in the third quarter of 2001, compared with 25-percent growth in the third quarter of 2000.

Not surprisingly, the terrorist attacks have made the economic situation in developing Asia even worse. With expectations that the U.S. recession will be prolonged and growth in exports will not revive quickly, the economic slowdown in developing Asia is expected to continue well into 2002. Moreover, international tensions are likely to have an adverse impact on tourism which will further harm the economies of Hong Kong, Singapore, and Thailand, where tourism accounts for more than 6 percent of GDP in each country [***16***]. Amidst worries of prolonged recessions among the developing Asian nations, domestic consumer demand has weakened as well, adding to the problems of the regional economies.

China has fared better than its neighbors, mostly because of the large state-sector investment expansion and stable private-sector consumption growth. Between 1998 and 2000, the Chinese government issued $43 billion worth of special bonds to finance investment in the public infrastructure and indicated that it may issue another $18 billion in 2001 and 2002 to ensure that economic growth continues [***17***]. China's GDP increased by 7.6 percent in the first three quarters of 2001, and it is expected to slip only slightly in 2002, to 7.2 percent. That said, China's accession into the World Trade Organization at the end of 2001 is expected to result in a short-term adverse impact on the economy, with fears that foreign competition may test China's often inefficient state-owned firms [***18***].

India has also thus far weathered the global economic slowdown fairly well, reporting higher than expected increments in income in 2001. At present, there are increasing signs of a slowdown in India as the growth in exports continues to decline and consumer spending also begins to falter. Passenger car sales in India fell by 22 percent between September 2000 and September 2001, and sales of commercial vehicles fell by 6 percent over the same time frame [***19***].

The slowdown in the industrialized countries' economies has affected the performance of economies in Central and South America. However, in two of the larger economies of the region, Brazil and Argentina, other circumstances have exacerbated the short-term economic risk. In Brazil, the largest economy of South America and the world's sixth largest economy, a persistent drought continued in 2001, leading to reduced industrial output as the government imposed a 20-percent cut in power use as part of its rationing program, in an effort to avoid blackouts [***20***]. Brazil's plan to diversify the electricity mix of the country by increasing thermal generation, particularly in terms of natural-gas-fired capacity, took on more urgency in 2001, partly in response to the ongoing threat of drought in a country that normally generates more than 80 percent of its electricity from hydropower. Reservoir levels fell 28 percent below capacity in key consuming regions of the country in the fall of 2001.

In 2001, the vulnerability of Brazil's electricity supply, in consort with the slowing industrial economies, led to reduced foreign investment, which had been a key contributor to the success of the nation's economy in 2000. With substantial support of foreign direct investment, the Brazilian government was able to handle a large current account deficit and was given a fair amount of latitude in the way it conducted monetary policy [***21***]. The central bank of Brazil increased interest rates in an attempt to limit the depreciation of the Brazilian real, but Brazil's benchmark interest rate (known as Selic) reached 19 percent in early 2002. With substantially lower exports in the face of the U.S. and world economic slowdown that began in 2001, growth in Brazil's GDP was only 1.5 percent in 2001 and is expected to be only 1.9 percent in 2002, compared with 4.5 percent in 2000 [***22***].

Argentina is another key economy of the Central and South America region, but it has also experienced several difficult economic years. When the Brazilian real was devalued in 1999, the close economic relationship between the two countries resulted in recessionary problems for the U.S. dollar-pegged Argentine currency. In fact, the country remained in the recession it has now been struggling with for more than 4 years. In early September 2001, the International Monetary Fund (IMF) lent assistance to Argentina, approving an increase of the country's available credit to $22 billion in an attempt to stabilize the economy and to help attract investment and improve output [***23***]. Subsequently, however, the IMF decided to withhold some $1.26 billion in payments to Argentina in December when it became concerned that the country had not implemented sufficient austerity measures [***24***].

The Argentine financial situation deteriorated so much that President de la Rua resigned in December 2001, and three new presidents were sworn in and resigned in

quick succession until Eduardo Duhalde took the office [***25***]. Duhalde announced a devaluation of the Argentine peso which would no longer be pegged to the U.S. dollar. The country also defaulted on a $28 million payment on a 2007 Italian lira bond—one of the largest defaults on record. There are worries that the default will make it nearly impossible to attract foreign investment into the country and that the new government may be turning away from the free-market policies it has implemented over the past decade in favor of more government control.

One bright spot among the economies of the world is the positive economic growth that continues in the countries of the former Soviet Union (FSU). In 2000, high world oil prices and a devalued ruble helped Russia—the region's largest economy—post its strongest year of economic growth, 8.3 percent, since the dissolution of the Soviet regime [***26***]. With the devaluation of the ruble making it difficult for consumers in the former Soviet republics to purchase imported products, domestic manufacturers began to increase production strongly. As the ruble regained value in 2001, the manufacturing sector slowed somewhat (as imported goods once again were able to compete with domestic goods), but relatively high world oil prices in the beginning of the year helped to keep economic growth positive in Russia, and its GDP grew by 5.3 percent in 2001.

The other FSU republics benefited from the improving Russian economy. In 2000, Ukraine posted its first increase in GDP since 1989, 5.8 percent, and an even stronger growth rate of 8.5 percent followed in 2001 [***27***, ***28***]. The country is a net importer of oil, and the high world oil prices did not benefit the Ukrainian economy. Instead, fiscal reform and strong growth in industrial output, construction activity, agriculture, and exports, along with fast-paced growth in domestic consumption and investment, helped to fuel Ukraine's economic growth. The government has managed to balance the state budget, cut expenditures, and begin the process of privatizing the energy sector as well as restructuring the country's banking sector. The international financial community has been encouraged by these changes and, in late September 2001, the IMF and the World Bank resumed their financing programs for Ukraine by releasing funds that had been on hold since 2000.

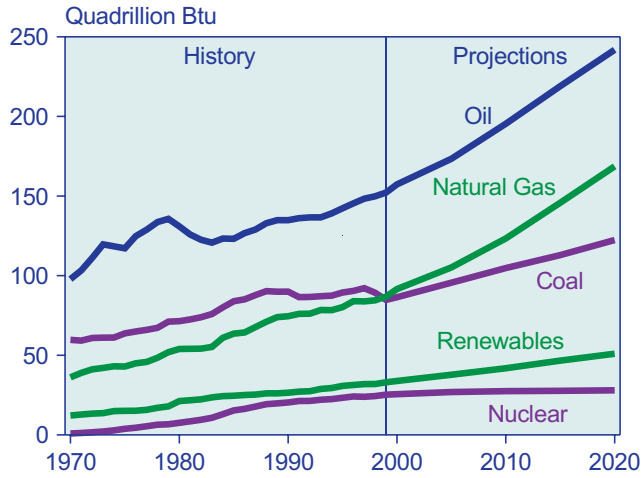
Another large FSU economy, Kazakhstan, has also performed well over the past 2 years, with GDP increasing by 9.6 percent in 2000 and 11.6 percent in 2001 [***29***]. Unlike Ukraine, Kazakhstan is an oil exporter, and much of its growth can be attributed to increased oil production. The government also supported private-sector growth by implementing tax cuts in 2001. With a banking sector that has been privatized and is widely considered to be among the best in the FSU, foreign direct investment has increased strongly over the past few years and is further encouraging the country's economic growth.

Outlook for Primary Energy Consumption

The *IEO2002* reference case projects that consumption of every primary energy source will increase over the 21-year forecast horizon (Figure 16). Most of the increment in energy consumption in the reference case is in the form of 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 non-fossil 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 *IEO2002* projections assume that government policies or programs in place as of October 1, 2001, will remain constant over the forecast horizon.

Oil is expected to remain the dominant energy fuel throughout the forecast period (maintaining a 40-percent share of total energy use between 1999 and 2020), as it has for decades. 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 *IEO2002* reference case projects declining oil use for

Figure 16. World Energy Consumption by Fuel Type, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

electricity generation, with other fuels (mostly 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 non-commercial 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 [***30***]. Because the natural gas infrastructure necessary to expand its 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 3.2 percent annually over the 1999-2020 period, more than twice the rate of growth for coal use. Natural gas consumption is projected to rise from 84 trillion cubic feet in 1999 to 162 trillion cubic feet in 2020, particularly for electricity generation. Gas is increasingly seen as the desired option for electric power, given the efficiency of 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.

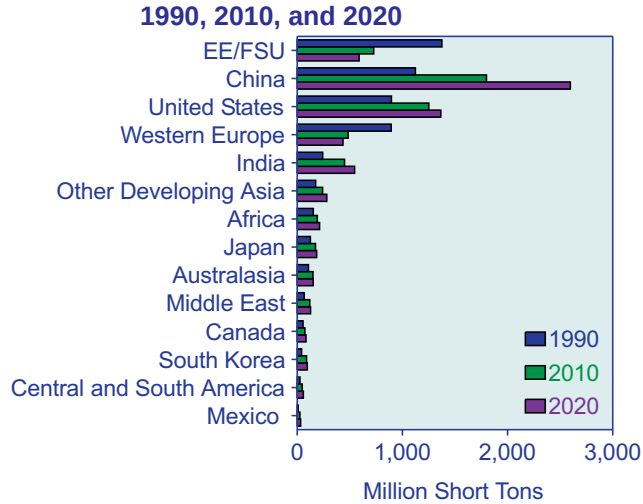
Coal use worldwide is projected to increase by 2.0 billion short tons (at a rate of 1.7 percent per year) between 1999 and 2020. Substantial declines in coal use are projected for Western Europe and the EE/FSU countries, where natural gas is increasingly being used to fuel new growth in electric power generation, and for other industrial and building sector uses (Figure 17). 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 85 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 2,396 billion kilowatthours in 1999 to 2,667 billion kilowatthours in 2020. Although past editions of this report have projected declines in nuclear electricity consumption toward the end of the forecast horizon, higher capacity utilization and fewer expected retirements of existing plants have resulted in a revision to the expectations for a decline in consumption. 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 primiarily to the owner and thus is an economic decision. In the *IEO2002* reference case, world nuclear capacity is projected to rise from 350 gigawatts in 2000 to 361 gigawatts in 2015 before falling 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 4.7 percent per year between 1999 and 2020. In particular, developing Asia is expected to see the greatest expansion in new nuclear generating capacity. The nations of developing Asia account for half of the 33 reactors currently under construction worldwide, including 8 in China, 4 in South Korea, 2 in India, and 2 in Taiwan.

Consumption of electricity from hydropower and other renewable energy sources is projected to grow by 2.1 percent annually in the *IEO2002* 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 expected to decline from 9 percent in 1999 to 8 percent in 2020. In the developing world, particularly in countries of developing Asia, such as China, India, Malaysia, and Vietnam, much of the growth in renewable energy use is driven by the installation of large-scale hydroelectric power plants. In the industrialized world, nonhydroelectric renewable energy sources are projected to predominate, particularly wind power in Western Europe and biomass and geothermal power in the United States.

Figure 17. World Coal Consumption by Region, 1990, 2010, and 2020



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

Outlook for Carbon Dioxide Emissions

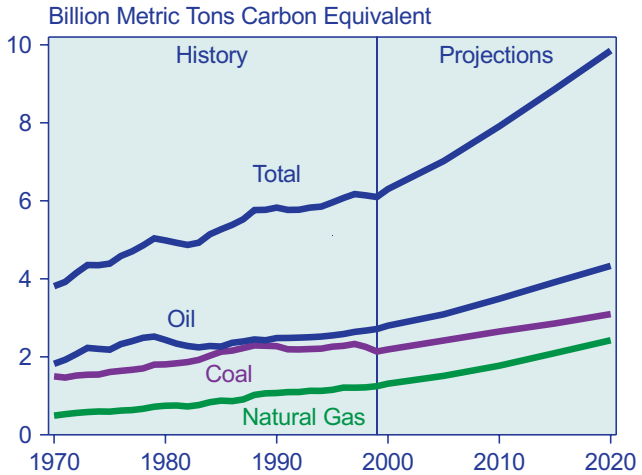
If fossil fuel consumption grows to the levels projected in the *IEO2002* reference case, carbon dioxide emissions are expected to rise to 7.9 billion metric tons carbon equivalent in 2010 and to 9.9 billion metric tons by 2020 (Figure 18). Much of the increase is expected in the developing countries, where emerging economies are expected to produce the largest increases in energy consumption, and carbon dioxide emissions are projected to grow by an average of 3.6 percent per year between 1999 and 2020. Developing countries alone account for 77 percent of the projected increment in world carbon emissions between 1990 and 2010 and 72 percent between 1990 and 2020 (Figure 19). Continued heavy reliance on coal and other fossil fuels projected for the developing countries is expected to drive the growth in carbon dioxide emissions over the forecast period.

In November 2001, participating member countries of the United Nations' seventh Conference of Parties (COP-7) met in Marrakesh, Morocco, and reached final agreement for the procedures and institutions needed to make the Kyoto Protocol fully operational. Although the United States was present at COP-6 in Bonn and at COP-7, it did not take an active role in the negotiations. In March 2001, the United States announced that it would not support the Kyoto Protocol. As of March 2002, 83 countries and the European Community had signed the treaty.[2] It was ratified by 49 signatories, only two of which (the Czech Republic and Romania) are among the Annex I countries[3] that would be required to limit or reduce their greenhouse gas emissions relative to 1990 levels under the terms of the Protocol.

On March 4, 2002, the European Union (EU) voted to ratify the Protocol, committing its 15 member countries to to reductions in greenhouse gas emissions as specified in the accord [***31***]. All the EU members are expected to ratify the Kyoto Protocol formally by June 1, 2002. No agreement has been reached among the EU member countries, however, with regard to the individual emission reductions that will be required. Denmark has argued that it was given a disporportionate share of the EU's total reduction burden.

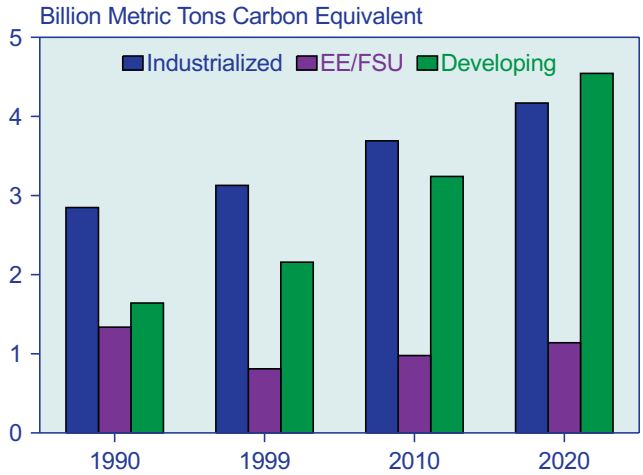
The Kyoto Protocol enters into force 90 days after it has been ratified by at least 55 Parties to the United Nations Framework Climate Change Convention (UNFCCC),

Figure 18. World Energy-Related Carbon Dioxide Emissions by Fuel Type, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

Figure 19. World Energy-Related Carbon Dioxide Emissions by Region, 1990-2020



Sources: **1990 and 1999:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

[2]The following 49 Parties to the Convention have ratified, accepted, acceded, or approved the Protocol as of March 6, 2002: Antigua and Barbuda, Argentina, Azerbaijan, Bahamas, Bangladesh, Barbados, Benin, Bolivia, Burundi, Colombia, Cook Islands, Cyprus, Czech Republic, Dominican Republic, Ecuador, El Salvador, Equatorial Guinea, Fiji, Gambia, Georgia, Guatemala, Guinea, Honduras, Jamaica, Kiribati, Lesotho, Malawi, Maldives, Malta, Mauritius, Mexico, Micronesia, Mongolia, Morocco, Nauru, Nicaragua, Niue, Palau, Panama, Paraguay, Romania, Samoa, Senegal, Trinidad and Tobago, Turkmenistan, Tuvalu, Uruguay, Uzbekistan, and Vanuatu.

[3]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. In addition, Kazakhstan proposed an amendment to the Marrakesh agreement, requesting that its name be added to the list of Annex I countries.

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 the other signatories.

Oil consumption is projected to account for the largest increment in worldwide carbon dioxide emissions. In 2020, emissions related to oil use are projected to be 1.9 billion metric tons carbon equivalent higher than the 1990 level. Emissions from natural gas use are expected to be 1.4 billion metric tons above 1990 levels in 2020 and emissions from coal 0.8 billion metric tons above 1990 levels. Although natural gas use is expected to increase at a faster rate than oil use, it is a less carbon-intensive fuel.

If the Kyoto Protocol became effective and the industrialized Annex I countries tried to reduce emissions solely by cutting fossil fuel consumption, reductions in energy use between 30 and 60 quadrillion Btu would be necessary (depending on the mix of fossil fuels used to achieve the reduction because of the relative differences in carbon intensity among the fossil fuels).[4] It is more likely, however, that most countries would attempt to reduce greenhouse gas emissions through alternative strategies, such as fuel switching, conservation measures, reforestation, emissions trading, and others.

Because there were no binding agreements to reduce or limit greenhouse gas emissions at the time this report was prepared, the *IEO2002* reference case projections do not account for the impact of any potential policy. Carbon dioxide emissions in the industrialized Annex I countries alone (i.e., excluding the transitional Annex I countries of the EE/FSU) are projected to grow to 3,527 million metric tons carbon equivalent in 2010 and 3,938 million metric tons in 2020, from 2,765 million metric tons in 1990. Approximately 43 percent of the expected increment is attributed to natural gas consumption, because many of the industrialized Annex I countries are increasingly turning to natural gas for new electricity generation because of its relative efficiency and low carbon dioxide emissions. Total Annex I emissions are projected to grow to 4,359 million metric tons carbon equivalent in 2010 and 4,900 million metric tons in 2020 from 3,897 million metric tons in 1990.

Oil accounts for 44 percent of the projected increase in carbon dioxide emissions in the industrial Annex I countries, which rely heavily on oil for transportation and, at present, have few economical alternatives. Only 12 percent of the projected increase in carbon dioxide emissions for the region are attributed to coal use. Projected decreases in coal consumption in Western Europe and moderate increases in the other industrialized countries account for coal's smaller portion of rising emissions.

Carbon dioxide emissions fell by 527 million metric tons in the transitional economies of the EE/FSU between 1990 and 1999, from 1,337 million metric tons to 810 million metric tons carbon equivalent. Emissions in the EE/FSU countries are expected to rise to 978 million metric tons carbon equivalent in 2010 and to 1,139 million metric tons in 2020, remaining below their 1990 level even at the end of the forecast horizon.

IEO2002 projects that the Annex I EE/FSU countries could provide 318 million metric tons of potential emissions allowances for the Annex I emissions reduction effort in 2010. Without allowance trading, the industrialized Annex I countries (including the United States) would have to reduce their emissions by a combined 948 million metric tons (or 27 percent) relative to the reference case projection for 2010. Because the EE/FSU Annex I countries are projected to emit about 318 million metric tons less than their Protocol targets, however, Annex I member countries as a whole would need to reduce their combined emissions by only 630 million metric tons (or 14 percent) in 2010 relative to the baseline projection. Removing the United States from the computations (given the country's announcement that it will not participate in this program), the 318 million metric tons of potential carbon dioxide emissions trading equivalents would mean that the remaining Kyoto Protocol participants would have to reduce their emissions by only 53 million metric tons—2 percent below the *IEO2002* reference case baseline in 2010.

Alternative Growth Cases

A major source of uncertainty in the *IEO2002* forecast is the expected rate of future economic growth. *IEO2002* 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

[4]This range was calculated by removing consumption of the most carbon-intensive fuel possible, coal, and the least carbon-intensive fossil fuel possible, natural gas, with the understanding that it probably would be impractical to reduce consumption of coal only, and a combination of fossil fuels would have to be reduced.

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 increased and decreased by 1.5 percentage points to provide the high and low economic growth case estimates.

Because China experienced 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, 3.0 percentage points are subtracted from the reference case GDP assumptions for China to form the low economic growth case, and 1.5 percentage points are added to the reference case to form the high economic growth case. For the EE/FSU region, 1.5 percentage points are subtracted from the reference case assumptions to derive the low economic growth case, and 3.0 percentage points are added for the high economic growth case.

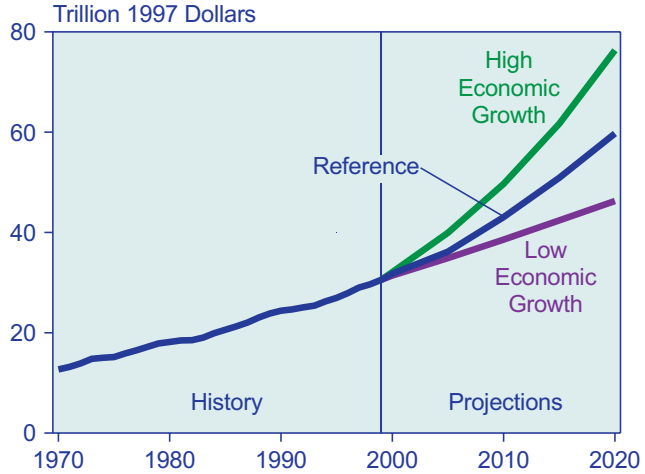
The *IEO2002* reference case shows total world energy consumption reaching 612 quadrillion Btu in 2020, with the industrialized world projected to consume 278 quadrillion Btu, the transitional EE/FSU countries 73 quadrillion Btu, and the developing world 260 quadrillion Btu. In the high economic growth case, total world energy use in 2020 is projected to be 728 quadrillion Btu, 117 quadrillion Btu higher than in the reference case (Figure 21). Under the assumptions of the low economic growth case, worldwide energy consumption in 2020 would be 88 quadrillion Btu lower than in the reference case (or 524 quadrillion Btu). Thus, there is a substantial range of 205 quadrillion Btu, or one-third of the total consumption projected for 2020 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 2020 are projected to total 8,365 million metric tons carbon equivalent in the low economic growth case (1,485 million metric tons less than the reference case projection) and 11,781 million metric tons carbon equivalent in the high economic growth case (1,930 million metric tons higher than the reference case projection).

Trends in Energy Intensity

Another way of quantifying the uncertainty surrounding a long-term forecast is to consider 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.

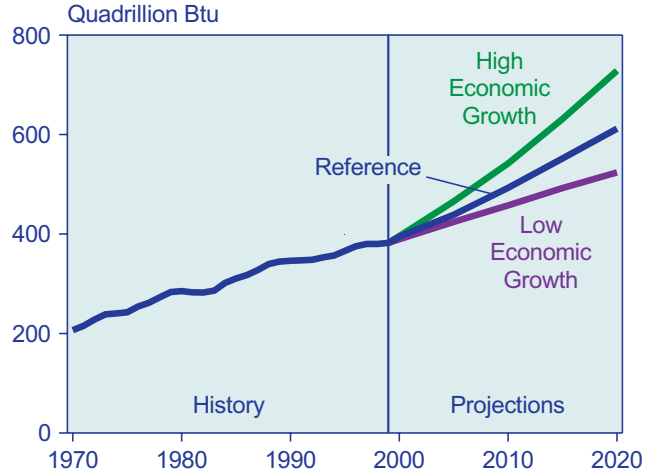
The historical behavior of energy intensity in the FSU is problematic. Since World War II, the EE/FSU economies

Figure 20. World Gross Domestic Product in Three Economic Growth Cases, 1970-2020



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** DRI-WEFA, *World Economic Outlook*, Vol. 1 (Lexington, MA, Third Quarter 2001); and EIA, World Energy Projection System (2002).

Figure 21. World Energy Consumption in Three Economic Growth Cases, 1970-2020



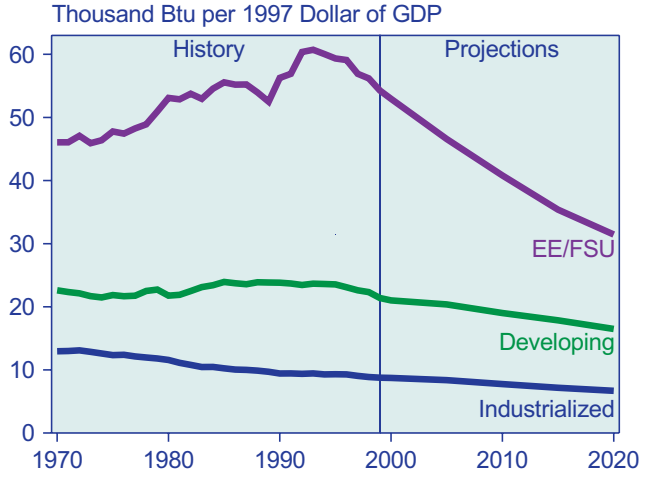
Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

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 were declining, 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 almost double that in the developing world and five times that in the industrialized world in 2020 (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 relatively high energy use per capita, but they also tend to be economies where per capita energy use is stable or changes very slowly, and increases in energy use tend to correlate with employment and population growth.

In the industrialized countries, there is a high penetration rate of modern appliances and motorized personal transportation equipment. To the extent that spending is directed to energy-consuming goods, it involves more often than not purchases of new equipment to replace old capital stock. The new stock is often more efficient than the equipment it replaces, resulting in a weaker link between income and energy demand. In developing countries, standards of living, while rising, tend to be low relative to those in more advanced economies.

Figure 22. World Energy Intensity by Region, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

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 1999, energy intensity in the developing world as a whole would fall by 69 percent between 1999 and 2020. Historically, the average of the largest single-year improvements in energy intensity for each of the developing nations has been 6 percent, and the single-year improvements for individual developing countries have ranged from 15 percent (China) to 3 percent (Brazil). If energy intensity in each of the developing countries were to improve annually over the forecast period at the highest historical rate of improvement recorded for the country in a single year, their combined energy consumption in 2020 would be 103 quadrillion Btu, as compared with the reference case projection of 260 quadrillion Btu.

If, on the other hand, energy intensity in each of the developing countries were to change annually at the lowest historical rate of improvement (or the highest rate of worsening) recorded for a single year from 1990 to 1999, energy intensity in the developing world as a whole would increase (worsen) by 120 percent between 1999 and 2020. 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 were to worsen (increase) annually over the forecast period at the highest historical rate recorded for the country in a single year (or to improve by the lowest rate recorded for countries where energy intensity has improved every year), their combined energy consumption in 2020 would climb to 744 quadrillion Btu in 2020—almost three times the reference case projection.

Forecast Comparisons

Another way to examine the uncertainty associated with the *IEO2002* projections is to compare them with those offered by other forecasters. Four organizations provide forecasts comparable to those in *IEO2002*. The International Energy Agency (IEA) provides "business as usual" projections to the year 2020 in its *World Energy Outlook 2000*. DRI-WEFA also provides energy forecasts by fuel to 2020 in its *World Energy Service: World Outlook 2000*. Petroleum Economics, Ltd. (PEL) and Petroleum Industry Research Associates (PIRA) publish world energy forecasts to the year 2015. For this comparison, 1997 is used as the base year for all the forecasts, because IEA does not publish data for any other historical years.

Regional breakouts among the forecasting groups vary, complicating the comparisons. For example, *IEO2002* includes Mexico in North America, but all the other forecasts include Mexico in Latin America. As a result, for purposes of this comparison, Mexico has been removed from North America in the *IEO2002* projections and added to Central and South America to form a "Latin America" country grouping that matches the other series. DRI-WEFA and PIRA include only Japan in industrialized Asia, whereas industrialized Asia in the *IEO2002* forecast comprises Japan, Australia, New Zealand, and the U.S. Territories. DRI-WEFA and *IEO2002* include 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 *IEO2002*. 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 2). The growth rates for energy consumption among the reference case forecasts for the 1997-2010 time period are similar, ranging between 2.0 and 2.1 percent per year. All the forecasts for total energy consumption fall well within the range of variation defined by the *IEO2002* low and high economic growth cases; in fact, all are within a range of 0.1 percentage point around the *IEO2002* reference case.

The regions for which the largest variations are seen among the forecasts are developing Asia, Latin America, and the EE/FSU. For developing Asia the projected average annual growth rates vary by 1.0 percentage point among the forecasts. DRI-WEFA projects the lowest growth in energy demand in the region at 3.1 percent per year between 1997 and 2010. However, DRI-WEFA only reports a projection for all of Asia, and lower expected growth rates in the industrialized countries of that region (i.e., Australia, Japan, and New Zealand) may be dampening the growth expected in the entire region. PEL projects the highest average growth for developing Asia in the 1997-2010 period, at 4.1 percent per year. *IEO2002* expects energy demand in developing Asia to grow by 3.3 percent annually over this time period.

Among the nations of developing Asia, the widest variations in the energy consumption forecasts are seen for China. PEL projects a growth rate of 4.6 percent per year, higher than projected in the *IEO2002* high economic growth case (4.1 percent per year). The *IEO2002* reference case projection for China defines the lower range of the forecasts, at 3.2 percent per year between 1997 and 2010.

Table 2. Comparison of Energy Consumption Growth Rates by Region, 1997-2010
(Average Annual Percent Growth)

Region	*IEO2002* Low Growth	*IEO2002* Reference	*IEO2002* High Growth	*IEO2001*	DRI-WEFA	IEA	PIRA	PEL
Industrialized Countries	**1.0**	**1.3**	**1.6**	**1.3**	**1.3**	**1.2**	**1.0**	**1.1**
United States and Canada	1.4	1.6	1.8	1.5	1.5	1.1	1.3	1.3
Western Europe	0.7	1.1	1.5	1.1	1.1	1.3	0.7	0.9
Asia	0.3	1.0	1.3	0.8	—	1.1	0.3[a]	0.5
EE/FSU	**0.6**	**1.4**	**2.0**	**1.1**	**1.1**	**1.4**	**2.1**	**0.9**
Developing Countries	**2.4**	**3.2**	**4.5**	**3.2**	**2.7**	**3.6**	**3.6**	**3.7**
Asia	2.3	3.3	4.7	3.3	3.1[c]	3.9	3.6	4.1
China	1.5	3.2	4.1	3.2	—	3.6	4.1	4.6
Other Asia[b]	3.1	3.4	5.2	3.3	—	4.2	3.3	3.8
Middle East	2.1	2.8	3.9	3.0	3.6	2.7	3.4	3.3
Africa	1.7	2.4	3.4	2.6	2.5	2.9	2.9	2.8
Latin America	2.9	3.6	4.9	3.6	3.7	3.3	2.6	2.8
Total World	**1.4**	**2.0**	**2.8**	**2.0**	**2.1**	**2.1**	**2.0**	**1.8**

[a]Japan only.
[b]Other Asia includes India and South Korea.
[c]Includes Japan, Australia, and New Zealand.

Sources: ***IEO2002*:** Energy Information Administration (EIA), World Energy Projection System (2002). ***IEO2001*:** EIA, *International Energy Outlook 2001*, DOE/EIA-0484(2001) (Washington, DC, March 2001), Table A1, p. 169. **DRI-WEFA:** DRI-WEFA, *World Energy Service: World Outlook 2000* (Lexington, MA, January 2001). **IEA:** International Energy Agency, *World Energy Outlook 2000* (Paris, France, November 2000), pp. 364-418. **PIRA:** PIRA Energy Group, *Retainer Client Seminar* (New York, NY, October 2001), Tables II-4, II-6, and II-7. **PEL:** Petroleum Economics, Ltd., *Oil and Energy Outlook to 2015* (London, United Kingdom, June 2001), Table 1.

The lower projection for China's energy consumption in the *IEO2002* forecast reflects a precipitous drop in energy use in China between 1997 and 1999, the historical year on which the *IEO2002* forecast is based. Consumption in China fell by 13 percent from 1997 to 1999, attributable to a 24-percent (6 quadrillion Btu) reduction in coal use. As a result, while *IEO2002* projects 5.1-percent annual growth in China's energy use between 1999 and 2010, the higher historical level in 1997 results in a lower growth projection for the 1997-2010 period. The other forecasts were based either on 1997 historical data (IEA) or on the expectation that energy use in China would increase between 1997 and 1999 (PIRA, for instance, estimated a 15-percent increase in energy use over the 2-year period).

Projections for the EE/FSU differ by a range of 1.2 percentage points, varying from 0.9 percent annual growth in energy demand between 1997 and 2010 (PEL) to 2.1 percent per year (PIRA). *IEO2002* projects that energy use in the EE/FSU will increase by 1.4 percent per year over the period. Energy consumption growth rates projected by PIRA fall outside the range defined by the *IEO2002* high and low economic growth cases, demonstrating the great uncertainties among the forecasts about how rapidly the economic recovery might progress over the next decade.

Latin America is another region for which large differences among the forecasts are evident. The projected growth rates for energy demand from 1997 to 2010 range from 2.6 percent per year (PIRA) to 3.7 percent (DRI-WEFA). The *IEO2002* reference case projects a growth rate of 3.6 percent per year for Latin America. Both PEL and PIRA projections fall below the lower bound of 2.9 percent per year defined by the *IEO2002* low economic growth case, reflecting different expectations of how several key economies of the region (notably, Brazil, Argentina, and Venezuela) may fare over the next several years.

IEO2002, PIRA, and PEL provide forecasts for energy use in 2015, the end of the PEL and PIRA forecast horizons (Table 3), and their projections for worldwide growth in energy consumption between 1997 and 2015 are similar, ranging from 1.9 percent per year (PEL) to 2.1 percent per year (*IEO2002* and PIRA). Regionally, however, there are some differences in the expectations for growth in energy demand. *IEO2002*, and to an even greater degree, PIRA, expect a much faster pace of recovery for the EE/FSU over the 1997-2015 period (1.5 and 2.2 percent per year, respectively) than does PEL (0.9 percent per year). *IEO2002* and PEL project similar annual growth rates for energy consumption in the countries of Eastern Europe between 1997 and 2015, with most of the variation in the EE/FSU forecasts resulting from their different expectations for the FSU. (PIRA does not publish a separate forecast for Eastern Europe and the FSU.) *IEO2002* expects much more robust recovery for energy use in the FSU, projecting an

Table 3. Comparison of Energy Consumption Growth Rates by Region, 1997-2015
(Average Annual Percent Growth)

Region	*IEO2002* Low Growth	*IEO2002* Reference	*IEO2002* High Growth	*IEO2001*	PIRA	PEL
Industrialized Countries	**0.9**	**1.3**	**1.6**	**1.2**	**0.9**	**0.4**
United States and Canada	1.3	1.5	1.8	1.4	1.1	1.1
Western Europe	0.6	1.0	1.4	1.0	0.7	0.8
Asia	0.3	1.0	1.3	0.9	0.5	0.3
EE/FSU	**0.8**	**1.5**	**2.4**	**1.4**	**2.2**	**0.9**
Former Soviet Union	0.9	1.7	2.5	1.5	—	0.7
Eastern Europe	0.5	1.1	2.0	1.2	—	1.5
Developing Countries	**2.4**	**3.3**	**4.6**	**3.4**	**3.4**	**3.5**
Asia	2.4	3.4	4.8	3.4	3.7	3.9
China	1.8	3.6	4.5	3.6	4.1	4.1
Other Asia[a]	2.9	3.3	5.0	3.3	3.3	3.6
Middle East	2.2	2.9	4.0	3.1	3.2	3.1
Africa	1.7	2.5	3.6	2.6	2.9	2.6
Latin America	2.8	3.8	4.9	3.7	2.7	2.8
Total World	**1.5**	**2.1**	**2.9**	**2.1**	**2.1**	**1.7**

[a]Other Asia includes India and South Korea.

Sources: ***IEO2002*:** Energy Information Administration (EIA), World Energy Projection System (2002). ***IEO2001*:** EIA, *International Energy Outlook 2001*, DOE/EIA-0484(2001) (Washington, DC, March 2001), Table A1, p. 169. **PIRA:** PIRA Energy Group, *Retainer Client Seminar* (New York, NY, October 2001), Tables II-4, II-6, and II-7. **PEL:** Petroleum Economics, Ltd., *Oil and Energy Outlook to 2015* (London, United Kingdom, June 2001).

average increase of 1.7 percent per year, than does PEL (0.7 percent per year).

There is also a significant difference among the three forecasts for the industrialized world over the 1997-2015 time period. The expected average annual growth in energy consumption for the industrialized nations ranges from 0.4 percent for PEL to 1.3 percent in the *IEO2002* reference case. The *IEO2002* projections are higher than PEL's and PIRA's for each of the three regions of the industrialized world. Higher expectations for developing Asia in the PEL and PIRA forecasts, however, offset the more pessimistic outlook for the industrialized nations.

IEO2002, IEA, and DRI-WEFA provide energy consumption projections for 2020. Table 4 provides a comparison of growth rates between 1997 and 2020 by region for the three forecasts. Again, the expectations for growth in total world energy consumption are similar, ranging from 2.0 percent per year (IEA) to 2.1 percent per year (DRI-WEFA and *IEO2002*). There are also relatively large differences among the forecasts for the EE/FSU, with growth rate projections ranging from 1.3 percent per year (DRI-WEFA) to 1.6 percent per year (IEA), with *IEO2002* at 1.5 percent per year.

There are some differences among the three forecasts for energy demand growth in the industrialized region from 1997 to 2020. IEA is less optimistic about growth in the United States and Canada (0.9 percent per year) than is DRI-WEFA (1.1 percent per year) or *IEO2002* (1.3 percent per year). DRI-WEFA, however, does not distinguish between industrialized and developing Asia in its forecast, and so it is difficult to assess what the expectations for Australia, Japan, and New Zealand may have meant for the DRI-WEFA industrialized world growth forecasts during this time period. Both *IEO2002* and IEA project that energy demand in Western Europe and the industrialized Asian countries will grow by 1.0 percent per year between 1997 and 2020.

Energy consumption projections for the developing world also vary in the three forecasts. While all three project the lowest growth rates among the developing world to be in Africa, *IEO2002* expects only a 2.5-percent average annual increase in energy consumption in the region, compared with DRI-WEFA's 2.6 percent and IEA's 2.8 percent. For the Middle East, IEA and *IEO2002* project average annual growth of 2.8 percent, whereas DRI-WEFA projects a 3.4-percent average annual increase over the forecast horizon. Both *IEO2002* and IEA also expect the highest growth in energy consumption to occur in developing Asia (including China); however, because Japan, Australia, and New Zealand cannot be disaggregated from DRI-WEFA's Asia consumption forecast, projected growth is dampened (3.0 percent per year).

Table 4. Comparison of Energy Consumption Growth Rates by Region, 1997-2020
(Average Annual Percent Growth)

Region	*IEO2002* Low Growth	*IEO2002* Reference	*IEO2002* High Growth	*IEO2001*	DRI-WEFA	IEA
Industrialized Countries	**0.9**	**1.2**	**1.5**	**1.1**	**1.1**	**0.9**
United States and Canada	1.2	1.4	1.7	1.3	1.2	0.9
Western Europe	0.6	1.0	1.3	1.0	0.9	1.0
Asia	0.3	1.0	1.3	0.9	—	1.0
EE/FSU	**0.8**	**1.5**	**2.4**	**1.4**	**1.3**	**1.6**
Former Soviet Union	0.9	1.6	2.5	1.5	1.4	—
Eastern Europe	0.6	1.2	2.1	1.3	0.9	—
Developing Countries	**2.3**	**3.3**	**4.5**	**3.4**	**2.7**	**3.4**
Asia	2.3	3.4	4.7	3.4	3.0	3.7
China	1.8	3.7	4.6	3.7	—	3.4
Other Asia[a]	2.7	3.2	4.8	3.2	—	4.0
Middle East	2.2	2.8	4.1	3.1	3.4	2.8
Africa	1.6	2.5	3.5	2.6	2.6	2.8
Latin America	2.6	3.8	4.7	3.7	3.5	3.1
Total World	**1.4**	**2.1**	**2.9**	**2.1**	**2.1**	**2.0**

[a]Other Asia includes India and South Korea.

Sources: ***IEO2002*:** Energy Information Administration (EIA), World Energy Projection System (2002). ***IEO2001*:** EIA, *International Energy Outlook 2001*, DOE/EIA-0484(2001) (Washington, DC, March 2001), Table A1, p. 169. **DRI-WEFA:** DRI-WEFA, *World Energy Service: World Outlook 2000* (Lexington, MA, January 2001). **IEA:** International Energy Agency, *World Energy Outlook 2000* (Paris, France, November 2000), pp. 364-418.

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 5). DRI-WEFA does not provide a breakout of nuclear and other sources of electricity generation but instead provides a single forecast for "primary electricity."

In terms of oil consumption, all the forecasts expect similar growth worldwide between 1997 and 2010. Oil demand is projected to increase by between 1.7 percent per year (PIRA) and 2.1 percent per year (DRI-WEFA and *IEO2002*). All the forecasts expect natural gas use to grow more rapidly than other fuels between 1997 and 2010. *IEO2002* expects slower growth in coal use over the 13-year period than do the other forecasts. *IEO2002* projects a 1.0-percent average annual growth rate for coal use, as compared with a range of 1.5 percent per year (PEL) to 1.8 percent per year (PIRA and DRI-WEFA) in the other forecasts.

IEO2002 is more optimistic about the prospects for nuclear electricity generation, projecting average growth of 1.1 percent per year between 1997 and 2010, as compared with the range of 0.6 percent per year (PEL) to 0.8 percent per year (IEA and PIRA) projected in the other forecasts. This optimism reflects the expectations that nuclear generators in the United States and other parts of the industrialized world and in the EE/FSU will not be retired as quickly as expected in prior outlooks.

PEL, PIRA, and *IEO2002* provide world energy consumption projections by fuel for 2015 (Table 6). The three forecasts reflect different views about expected growth by fuel between 1997 and 2015. *IEO2002* expects strong growth in natural gas use to result in slow growth in coal consumption, particularly for electric power generation. PEL expects natural gas use to grow more slowly and coal use to grow more rapidly than projected in *IEO2002*. PIRA expects faster growth in natural gas and coal use but slower growth for nuclear power and renewables than projected in *IEO2002*. Moreover,

Table 5. Comparison of World Energy Consumption Growth Rates by Fuel, 1997-2010
(Average Annual Percent Growth)

Fuel	*IEO2002* Low Growth	*IEO2002* Reference	*IEO2002* High Growth	*IEO2001*	DRI-WEFA	IEA	PIRA	PEL
Oil	1.6	2.1	2.9	2.1	2.1	2.0	1.7	1.6
Natural Gas	2.5	3.0	3.8	3.1	3.4	2.8	3.4	1.5
Coal	0.2	1.0	1.7	0.8	1.8	1.7	1.8	2.9
Nuclear	0.7	1.1	1.5	1.0	—[a]	0.8	0.8	1.9
Renewable/Other	1.6	2.1	2.9	2.2	—[a]	2.5	1.8	0.6
Total	**1.4**	**2.0**	**2.8**	**2.0**	**2.1**	**2.1**	**2.0**	**1.8**
Primary Electricity	1.2	1.7	2.3	1.7	1.5	1.5	1.3	1.3

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

Sources: ***IEO2002*:** Energy Information Administration (EIA), World Energy Projection System (2002). ***IEO2001*:** EIA, *International Energy Outlook 2001*, DOE/EIA-0484(2001) (Washington, DC, March 2001), Table A1, p. 169. **DRI-WEFA:** DRI-WEFA, *World Energy Service: World Outlook 2000* (Lexington, MA, January 2001). **IEA:** International Energy Agency, *World Energy Outlook 2000* (Paris, France, November 2000), pp. 364-418. **PIRA:** PIRA Energy Group, *Retainer Client Seminar* (New York, NY, October 2001), Table II-8. **PEL:** Petroleum Economics, Ltd., *Oil and Energy Outlook to 2015* (London, United Kingdom, June 2001).

Table 6. Comparison of World Energy Consumption Growth Rates by Fuel, 1997-2015
(Average Annual Percent Growth)

Fuel	*IEO2002* Low Growth	*IEO2002* Reference	*IEO2002* High Growth	*IEO2001*	PIRA	PEL
Oil	1.6	2.2	3.0	2.2	1.7	1.7
Natural Gas	2.5	3.1	3.9	3.1	3.4	1.3
Coal	0.3	1.1	1.9	1.0	1.8	2.7
Nuclear	0.4	0.8	1.2	0.8	0.6	1.8
Renewable/Other	1.5	2.1	2.9	2.1	1.9	0.2
Total	**1.5**	**2.1**	**2.9**	**2.1**	**2.1**	**1.7**
Primary Electricity	1.0	1.6	2.2	1.6	1.3	1.3

Sources: ***IEO2002*:** Energy Information Administration (EIA), World Energy Projection System (2002). ***IEO2001*:** EIA, *International Energy Outlook 2001*, DOE/EIA-0484(2001) (Washington, DC, March 2001), Table A1, p. 169. **PIRA:** PIRA Energy Group, *Retainer Client Seminar* (New York, NY, October 2001), Table II-8. **PEL:** Petroleum Economics, Ltd., *Oil and Energy Outlook to 2015* (London, United Kingdom, June 2001).

IEO2002 projects much higher growth in nuclear power use (0.8 percent per year) than does PEL (0.2 percent per year).

IEO2002, IEA, and DRI-WEFA are the only forecasts that provide projections for 2020 (Table 7). The three forecasts show similar expectations for growth in oil and natural gas use but different expectations for coal and nuclear power. In the *IEO2002* reference case, coal use is projected to increase by 1.2 percent per year, whereas the IEA and DRI-WEFA projections are considerably higher, at 1.7 and 1.9 percent per year, respectively. Much of the future coal use in the *IEO2002* projection is offset by a more robust forecast for nuclear power than in either of the other two forecasts. *IEO2002* expects primary electricity use (nuclear power and renewable energy) to increase by 1.5 percent per year, compared with 1.0 percent per year in the IEA and DRI-WEFA forecasts.

Table 7. Comparison of World Energy Consumption Growth Rates by Fuel, 1997-2020
(Average Annual Percent Growth)

Fuel	*IEO2002* Low Growth	*IEO2002* Reference	*IEO2002* High Growth	*IEO2001*	DRI-WEFA	IEA
Oil	1.5	2.1	3.0	2.2	2.1	1.9
Natural Gas	2.5	3.1	3.9	3.1	3.2	2.7
Coal	0.3	1.2	2.0	1.0	1.9	1.7
Nuclear	0.2	0.7	1.1	0.5	—[a]	0.0
Renewable/Other	1.3	2.1	2.8	2.0	—[a]	2.3
Total	**1.4**	**2.1**	**2.9**	**2.1**	**2.1**	**2.0**
Primary Electricity	0.9	1.5	2.1	1.4	1.0	1.0

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

Sources: ***IEO2002*:** Energy Information Administration (EIA), World Energy Projection System (2002). ***IEO2001*:** EIA, *International Energy Outlook 2001*, DOE/EIA-0484(2001) (Washington, DC, March 2001), Table A1, p. 169. **DRI-WEFA:** DRI-WEFA, *World Energy Service: World Outlook 2000* (Lexington, MA, January 2001). **IEA:** International Energy Agency, *World Energy Outlook 2000* (Paris, France, November 2000), pp. 364-418.

References

1. Energy Information Administration, *Short-Term Energy Outlook*, November web edition (November 6, 2001), web site www.eia.doe.gov.
2. "Oil Prices Sink After OPEC Dithers," Reuters News Service (November 15, 2001), web site www.msnbc.com.
3. Cambridge Energy Research Associates, "Signs of an OPEC and Non-OPEC Truce," *CERA Alert (Cambridge, MA, December 6, 2001), p. 1.*
4. D. Rohlfs and N. Sharushkina, "Mousetrap: Russia Readies for Price War with OPEC," *NEFTE Compass*, Vol. 10, No. 48 (November 29, 2001), p. 6.
5. "Russia To Cut Oil Exports," *The New York Times Web Edition* (December 5, 2001), web site www.nytimes.com.
6. Energy Information Administration, *Short-Term Energy Outlook* (March 2002) web site www.eia.doe.gov/steo/pub/contents.html.
7. P. Kiernan, "Crude Trades Sideways; OPEC Yet To Get Supply Cut Pledge from Russia," *The Oil Daily*, Vol. 52, No. 42 (March 5, 2002), p. 3.
8. R.W. Stevenson, "Economists Make It Official: U.S. Is in Recession," *The New York Times* (November 27, 2001), p. C1.
9. T. Lee and D. Ryan, "Asia Economic Summary: Fourth Quarter 2001," *DRI-WEFA, Asia Economic Outlook, Fourth Quarter 2001* (Eddystone, PA, November 5, 2001), p. EX.1.
10. D. Ryan, "Japan: Outlook," *DRI-WEFA, Asia Economic Outlook, Fourth Quarter 2001* (Eddystone, PA, November 2001), p. JA.4-6.
11. European Central Bank, "Monetary Policy Decisions," Press Release (September 17, 2001), web site www.ecb.int.
12. "Germany Edges Towards Recession," DRI-WEFA Economic Briefings (November 22, 2001), web site www.dri-wefa.com.
13. "French Growth Stronger Than Expected in Third Quarter," DRI-WEFA Economic Briefings (November 23, 2001), web site www.dri-wefa.com.
14. A. Stockman, "United Kingdom: Short-Term Economic Growth," *DRI-WEFA, Industrialized Countries Monthly Monitor* (Eddystone, PA, October 2001), p. UK.90.
15. T. Lee and D. Ryan, "Asia Executive Summary," *DRI-WEFA, Asia Economic Outlook, Fourth Quarter 2001* (Eddystone, PA, November 2001), p. EX.1.

16. T. Lee and D. Ryan, "Asia Executive Summary," *DRI-WEFA, Asia Economic Outlook, Fourth Quarter 2001* (Eddystone, PA, November 2001), p. EX.1.

17. T. Lee, "China: Outlook," *DRI-WEFA, Asia Economic Outlook, Fourth Quarter 2001* (Eddystone, PA, November 2001), p. CH.4-5.

18. "China's WTO Membership: A Great Gamble Beijing Cannot Refuse," DRI-WEFA Economic Briefing (November 16, 2001), web site www.dri-wefa.com.

19. J. Narasimhan, "India: Outlook and Recent Developments," *DRI-WEFA, Asia Economic Outlook, Fourth Quarter 2001* (Eddystone, PA, November 2001), p. ID.4-5.

20. P. Gall, "Brazil's Natural Gas Market Simultaneously Beckons, Threatens," *The Oil Daily*, Vol. 51, No. 169 (August 31, 2001), p. 4.

21. DRI-WEFA, *Latin American Monthly Monitor* (Eddystone, PA, November 2001), p. iv.

22. DRI-WEFA, *Latin American Monthly Monitor* (Eddystone, PA, November 2001), p. BZ.2.

23. International Monetary Fund, "IMF Augments Argentina Stand-By Credit to $21.57 Billion, and Completes Fourth Review," Press Release No. 01/37 (September 7, 2001).

24. "Argentines Fear Economic Crisis," *The New York Times Web Edition* (December 10, 2001), web site www.nytimes.com.

25. "Argentina Devalues Currency and Defaults on Its Debts," MSNBC News (January 3, 2001), web site www.msnbc.com.

26. K. Crane, "The CIS: Is Growth Here To Stay?," *PlanEcon Review and Outlook for the Former Soviet Republic* (Washington, DC, October 2001), p. i.

27. K. Crane, "The CIS: Is Growth Here To Stay?," *PlanEcon Review and Outlook for the Former Soviet Republic* (Washington, DC, October 2001), p. vii.

28. Z. Tabernacki, "Outlook for Ukraine," *PlanEcon Review and Outlook for the Former Soviet Republic* (Washington, DC, October 2001), p. 31-33.

29. K. Crane, "Outlook for Kazakhstan," *PlanEcon Review and Outlook for the Former Soviet Republic* (Washington, DC, October 2001), p. 73-75.

30. D.F. Barnes et al., "Tackling the Rural Energy Problem in Developing Countries," *Finance & Development*, Vol. 34, No. 2 (June 1997), pp. 11-15.

31. "EU Ministers Push Kyoto Pact Forward: Agree to Speedy Radification, But Not on Pollution Limits," *The Toronto Star* (March 4, 2002), web site www.thestar.com.

World Oil Markets

In the IEO2002 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 2020 as the oil resource base is expanded.

Throughout the last quarter of 2001, crude oil prices were below the range preferred by Organization of Petroleum Exporting Countries (OPEC) producers ($22 to $28 per barrel for the OPEC basket price). Three factors contributed to the softening of prices late in 2001. First, there was only a loose adherence by some OPEC producers to announced cutbacks in production. Second, the long-anticipated increase in non-OPEC production brought about by the high price environment of 2000 and 2001 began to materialize. Third, world demand growth continued to be extremely sluggish.

World oil prices are expected to show some recovery in 2002, assuming disciplined adherence by OPEC producers to their stated cutback intentions as well as additional supply reductions by several key non-OPEC producers. Russia, Norway, Mexico, Oman, and Angola all have committed to production cutbacks in order to firm up prices. It remains to be seen, however, whether such a coalition of OPEC and non-OPEC producers can demonstrate the restraint necessary to manage the market. Despite evidence that OPEC has achieved some of its price goals in recent years, production cutback strategies traditionally had only sporadic success.

World oil consumption in 2001 rose by less than 100 thousand barrels per day, scattered evenly among the industrialized nations (mainly Western Europe) and developing nations (mainly Latin America). 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 American oil demand has also experienced 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 was a slight decline in demand in 2001. Global oil demand in 2002 is expected to grow by about 600,000 barrels per day [***1***].

OPEC members (not including Iraq) have agreed to cutbacks that will reduce current production levels by about 1.7 million barrels per day, in response to indications of price weakness in the near-term market. It is anticipated that the cutbacks will keep the world oil price (U.S. refiner acquisition cost for imports) commensurate with the lower end of the OPEC target range for the basket price of $22 to $28 per barrel throughout 2002, although additional production corrections are certainly possible. Iraq's oil production and export volumes have been continuing at the sanction levels dictated by the United Nations Security Council. Those levels are assumed to remain in effect throughout all of 2002.

Historically, OPEC's market management strategies have often ended in failure. OPEC's recent successes have been the result of tight market conditions and disciplined participation by OPEC members. Currently, spare production capacity worldwide—with the exception of two or three Persian Gulf members of OPEC—is negligible, making OPEC's consensus building 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. Although 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, non-OPEC production increased by 1.1 million barrels per day in 2000 and by an additional estimated 700 thousand barrels per day in 2001, and it is expected to increase by another 1 million barrels per day in 2002. Almost one-half of the worldwide non-OPEC production increase 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 return to OPEC's preferred range in response to production cutback strategies, or will the anticipated increase in non-OPEC production temper the price rise? 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

technology guarantee that oil supply development will move forward even if a low world oil price environment returns?

Although oil prices more than doubled in real terms from 1998 to 1999 and have softened considerably since then, such developments are not indicative of the trend in the *International Energy Outlook 2002* (*IEO2002*) reference case. In the short term, oil prices are expected to decline slightly until agreed-upon OPEC production cutbacks are put into place along with some non-OPEC cooperation early in 2002. From their anticipated level in 2002, oil prices are expected to increase gradually to 2020. 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 2020, requiring an increment to world production capability of almost 44 million barrels per day relative to current capacity. OPEC producers are expected to be the major suppliers of increased production requirements, but non-OPEC supply is expected to remain highly competitive, with major increments to supply coming from offshore resources, especially in the Caspian Basin, Latin America, and deepwater West Africa.

Over the past 25 years, oil prices have been highly volatile. In the future, one can expect volatile behavior to recur principally because of unforeseen 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 long sustained. High real prices deter consumption and encourage the emergence of significant competition from marginal but large sources of oil and other energy supplies. Persistently low prices have the opposite effects.

Limits to long-term oil price escalation include substitution of other fuels (such as natural gas) for oil, marginal sources of conventional oil that become reserves (i.e., economically viable) when prices rise, and nonconventional sources of oil that become reserves at still higher prices. Advances in exploration and production technologies are likely to bring down prices when such additional oil resources become part of the reserve base. The *IEO2002* 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 oil market analysts, however, who find this viewpoint to be overly optimistic, based on what they consider to be a significant overestimation of both proven reserves and ultimately recoverable resources (see box on page 25).

Highlights of the *IEO2002* projections for the world oil market are as follows:

- The reference case oil price projection shows an increase of more than $4 per barrel over current prices out to 2003, followed by a modest 0.6-percent average annual increase from 2003 to 2020.
- 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, especially the Caspian Basin region.
- Economic development in Asia is crucial to long-term growth in 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 *IEO2002* reference case projections are significant. The international war on terrorism, uncertain economic recovery in developing Asia and Japan, the success of China's economic reforms and its political situation, 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 *IEO2002* reference case is somewhat different from that in *IEO2001*. In last year's reference case price path, only modest relief was expected in 2001 from the high oil prices of late 1999 and 2000, primarily because of OPEC's demonstrated ability to adhere to announced production cutbacks. This year's reference case price path shows prices falling to $21.55 per barrel in 2001, based on weak demand, less-than-anticipated non-OPEC supply, some cheating by OPEC members in their market management strategies, and

Oil Resources in the 21st Century: What Shortage?

In the late 1990s it became fashionable to warn the world of a looming shortage in worldwide oil supplies. Much of the pessimistic speculation was related to a disbelief in the estimates of oil reserves, especially those claimed by OPEC nations throughout the 1980s. Although the controversy regarding oil reserves has dissipated somewhat, there has been much evidence that the long-term production potential of oil resources is healthy. This is true for both conventional oil and nonconventional resources.

The U.S. Geological Survey, in its most recent assessment of oil's long-term production potential, identified at least 3 trillion barrels (mean estimate) of ultimately recoverable conventional oil worldwide.[a] Because history has shown that only about one-fourth of the oil estimated to be "ultimately recoverable" has actually been produced, rough calculations would place the likely peak in worldwide conventional oil production at some point beyond 2020.

No one doubts that fossil fuels are subject to depletion, and that depletion leads to scarcity, which in turn leads to higher prices. Resources are defined as nonconventional when they cannot be produced economically at today's prices and technology. With higher prices, the gap between conventional oil and nonconventional resources narrows. Ultimately, a combination of escalating prices and technological enhancements will transform the nonconventional into the conventional. Much of the pessimism about oil resources has been focused entirely on conventional resources. However, the decade of the 1990s saw technological advances that helped bring down the cost of producing liquid fuels from several nonconventional sources, including heavy oils, tar sands, and natural gas.

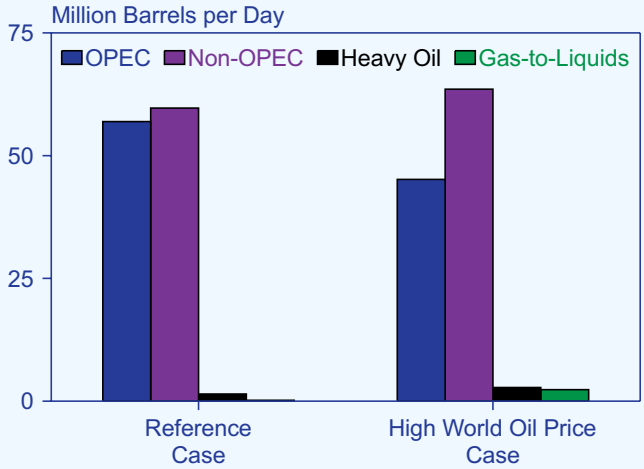
Heavy oils typically have an API gravity of less than 24 degrees and will not flow on their own at standard reservoir temperatures. Tar sands are similar, but with more viscous oil and located closer to the surface. More than 3.3 trillion barrels (oil in place) of heavy oil and tar sands is estimated worldwide, with Canada and Venezuela having the most significant deposits. There are two distinct methodologies for recovering these resources from the ground. For deposits close enough to the surface, mining is feasible. For deeper deposits, steam injection can be used to heat the oil, allowing it to flow more like conventional oil. Once the oil has been retrieved, it still must be cleaned and upgraded before it will behave more like conventional refinery feedstocks.[b] The reference case in *IEO2002* shows development of almost 900 thousand barrels per day in heavy oils and tar sands production capacity over the forecast period. The high world oil price case shows an increase of almost 2.2 million barrels per day of production capacity by 2020. All of the new capacity is expected to be built in Canada and Venezuela. It is assumed that this production capacity could be economically developed and produced at prices in the range of $23 to $25 per barrel.

Significant portions of the world's natural gas resources lie in remote locations or are found in small accumulations. Development of such projects usually is discouraged, because delivery via pipeline or LNG tanker is often uneconomical. Using an updated version of a technology that has existed since World War II (Fischer-Tropsch), natural gas molecules can be recombined as liquid synthetic petroleum products. Gas-to-liquids (GTL) technology is an attractive marketing option, because the infrastructure for petroleum products is already in place. The GTL technology also has enough versatility to accommodate smaller gas deposits economically. In addition, GTL offers a number of environmental advantages that may enhance its economic attractiveness.[c]

A few GTL projects are expected to be built in the *IEO2002* reference case because of convenient access to

(continued on page 26)

Projected OPEC, Non-OPEC, and Nonconventional Oil Supply in 2020



Source: Energy Information Administration, World Energy Projection System (2002).

[a]U.S. Geological Survey, *World Petroleum Assessment 2000*, web site http://greenwood.cr.usgs.gov/energy/WorldEnergy/DDS-60.
[b]National Energy Board, *Canada's Oil Sands: A Supply and Market Outlook to 2015* (Calgary, Alberta, October 2000), p. 22.
[c]Energy Information Administration, *International Energy Outlook 2000*, DOE/EIA-0484(2000) (Washington, DC, March 2000), p. 59.

Oil Resources in the 21st Century: What Shortage? (Continued)

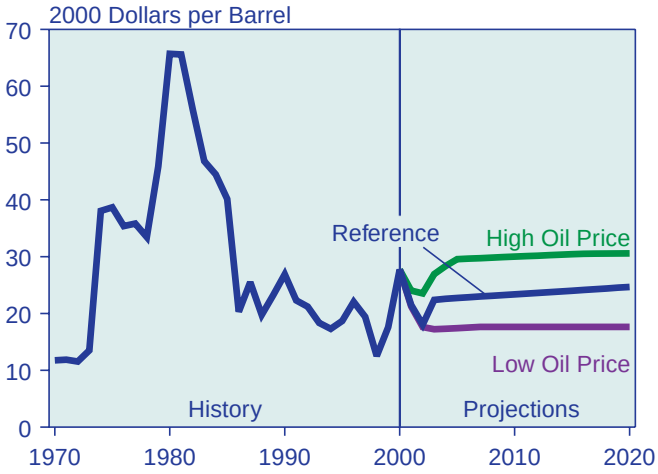
distribution infrastructure. In the high world oil price case, an increase of more than 2.3 million barrels per day is projected over the forecast period, including projects in Latin America, the Pacific Rim, the Middle East, the former Soviet Union, and the United States. It is assumed that this production capacity could be economically developed and produced at prices in the range of $26 to $28 per barrel. The figure below compares the supply-side response in the *IEO2002* high world oil price case with that in the reference case.

In the *IEO2002* high world oil price case, heavy oil, tar sands, and GTL are the only nonconventional oil supplies that are economically viable. It is conceivable, however, that oil prices could be substantially higher. For example, if the OPEC producers adopt a conservative capacity expansion strategy, prices could more than double in real terms over the forecast period. Such a steady diet of high oil prices would further alter the supply side of the market in ways even beyond those suggested by heavy oil, tar sands, and GTL. For example, other nonconventional liquids might begin to make inroads into such a market. Coal-to-liquids technologies and even shale oil (with enormous worldwide reserves that dwarf those of conventional oil) might be introduced into the supply mix.

Any long-term strategy that has as an objective the achievement of sustained high prices is unlikely to be successful, given the feasibility of making nonconventional supplies economical at those prices. The inability to predict accurately the diminishing costs of current technologies or the enhanced capabilities of new technologies could make a long-term high price strategy a risky one for OPEC. Reasonable arguments can be made that any artificial (non-market) means of production management might achieve short-term objectives but are unlikely to optimize revenues or stabilize market share in the long run. It is anticipated that nonconventional oil resources will act as a buffer against prolonged periods of high oil prices well into the middle of this century, and perhaps well beyond.

Saudi Arabia's decision to postpone production cutbacks in the aftermath of the September 11, 2001, terrorist attacks on the United States. In both outlooks, the price trajectory in the reference case beyond 2005 shows a gradual increase of about 0.5 percent per year to 2020. Three possible long-term price paths are shown in Figure 23. In the reference case, projected prices reach $24.68 in 2020 (all prices in 2000 dollars unless otherwise noted). In nominal dollars, the reference case price is expected to exceed $42 in 2020. In the low price case, prices are projected to reach $17.41 by 2005 and to remain at about that level out to 2020. In the high price case, prices are projected to reach $30.50 by 2015 and to remain at about that level out to 2020. The projected leveling off in the high price case is due to the market penetration of alternative energy supplies that could become economically viable at that price.

Figure 23. World Oil Prices in Three Cases, 1970-2020



Sources: **History:** Energy Information Administration (EIA), *Annual Energy Review 2000*, DOE/EIA-0384(2000) (Washington, DC, July 2001). **Projections:** 2000-2002—EIA, *Short-Term Energy Outlook*, on-line version (January 8, 2002), web site www.eia.doe.gov/emeu/steo/pub/contents.html. 2003-2020—EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383 (2002) (Washington, DC, December 2001).

In all the *IEO2002* oil price cases, oil demand is expected to rise significantly over the projection period. In the high and low world oil price cases, the projected rise in oil consumption ranges from a low of 39 million barrels per day to a high of 50 million barrels per day, respectively. There is widespread agreement that resources are not a key constraint on world demand to 2020. Rather more important are the political, economic, and environmental circumstances that could shape developments in oil supply and demand.

World Oil Demand

Over the next two decades, oil is projected to remain the dominant fuel in the world energy mix, accounting for 40 percent of total energy consumption worldwide throughout the forecast period. Total world oil demand is expected to grow by 2.2 percent annually, rising from 74.9 million barrels per day in 1999 to 118.6 million barrels per day in 2020 (Figure 24). In the industrialized world, oil use grows much more slowly than the world average, at 1.3 percent per year, as oil markets reach saturation levels in all end use sectors except electric

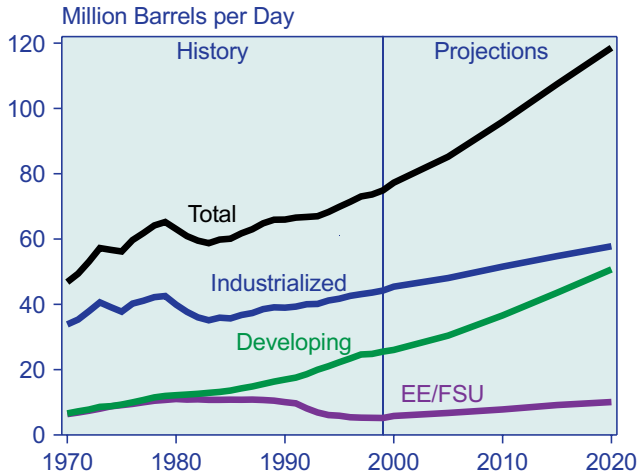
power. Oil use in the industrialized world is expected to decline as natural gas becomes the fuel of choice for new electricity generation capacity.

The highest growth in oil demand is projected for developing Asia, at 3.7 percent per year and accounting for 35 percent of the increment in oil consumption in the forecast period (Figure 25). Oil intensity is projected to remain high in developing countries relative to that in the industrial world (Figure 26). Industrial processes continue to require large amounts of fuel relative to output. Even in the transportation sector, the motor vehicle fleets in developing countries burn large amounts of gasoline or diesel fuel relative to their size, power, and capacity, as is the case in China. Relatively high levels of oil intensity are expected to contribute to the fast-paced growth of oil use in the region as a whole [***2***].

World oil demand increased modestly in 2001, by 100 thousand barrels per day [***3***]. Early in 2001 the world oil market was extremely tight. Prices were high and there was concern that there might be shortages in supply. In the last quarter of 2001, however, prices eased considerably as a result of the economic slowdown in the United States and a sharp decrease in jet fuel demand after the September terrorist attacks. The current global economic slowdown is expected to have only short-term effects on oil demand. As the world economy recovers, oil demand is expected to resume an upward trend in the *IEO2002* reference case projection. In general, disruptions in oil demand have historically been short-lived. For instance, in 1990 and 1991 many economies were in recession, and air travel fell sharply in reaction to the Gulf War. As the global economy recovered, however, oil demand returned to its upward trend.

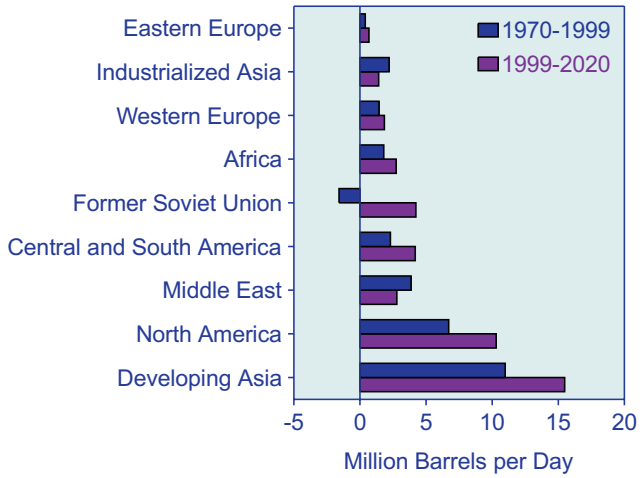
The transportation sector is expected to account for much of the worldwide increase in oil use over the projection period. By 2020, transport is projected to account for 55 percent of world oil demand, based on expectations that there will be no economically viable substitutes for oil as a transportation fuel, and that private ownership of motor vehicles will continue to expand in most of the developing countries.

Figure 24. World Oil Consumption by Region, 1970-2020



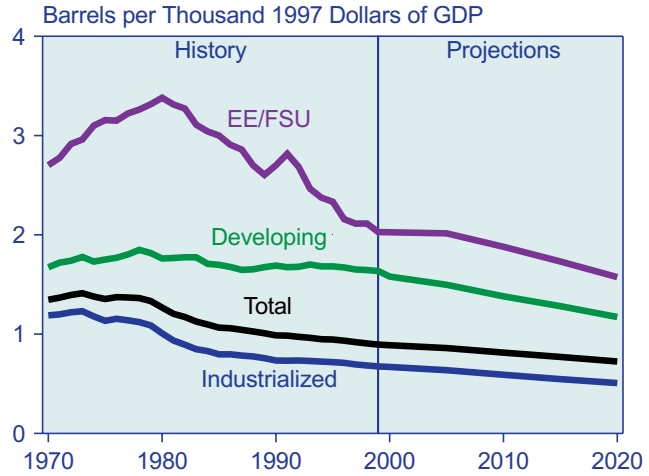
Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

Figure 25. Increments in Oil Consumption by Region, 1970-1999 and 1999-2020



Sources: **1970 and 1999:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **2020:** EIA, World Energy Projection System (2002).

Figure 26. Oil Intensity by Region, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

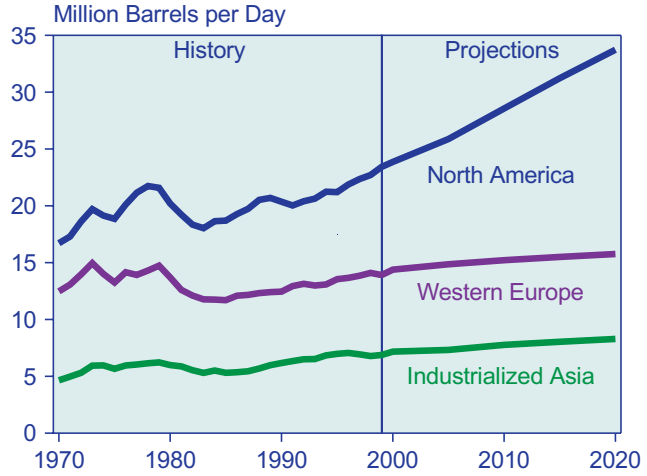
North America

Petroleum product consumption in North America is projected to increase by 10.3 million barrels per day from 1999 to 2020, at an average annual growth rate of 1.8 percent. This is by far the largest expected increase among the industrialized regions (Figure 27).

The effects of the slowing global economy and the recession in the United States are expected to affect demand for all petroleum products in North America. In the short term, the largest expected reduction in oil demand is in the jet fuel market. U.S. jet fuel demand declined by almost 4 percent in 2001 and is expected to be down by 10 percent in the first half of 2002 [***4***]. Over the past year, high jet fuel prices, the largest component of airline costs, contributed to the slowdown of air passenger travel and air cargo shipments [***5***]. The slowdown became steeper after the September 11 terrorist attacks. Most airlines in North America announced significant reductions in flight schedules, averaging 20 to 25 percent from normal levels [***6***]. There is considerable uncertainty in the short term about the pace of recovery of North American airline travel and jet fuel demand.

The United States is the largest consumer of oil in the world, accounting for more than one-fourth of total world demand. The *IEO2002* reference case projects that primary consumption of oil in the United States will increase by 1.5 percent annually from 1999 to 2020, and that oil's share in the U.S. energy mix will increase slightly, from 39.4 percent in 1999 to 39.7 percent in 2020, totaling 26.7 million barrels per day.

Figure 27. Oil Consumption in the Industrialized World by Region, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

The economic slowdown that started in late 2000 and the terrorist attack on the United States in September 2001 have worsened the short-term demand outlook not only for jet fuel but for all other petroleum products. Distillate fuel use in the United States fell between April and June 2001, when lower natural gas prices led most industrial sector consumers and electric utilities to switch back to natural gas from distillates. Faltering consumer spending and business investment also slowed the growth in demand for petrochemicals and for liquefied petroleum gas (LPG) and naphtha feedstocks as well.

Over the next 20 years, the expected trend of moderate oil prices should facilitate growth in U.S. oil demand, centering on the transportation fuels. The growing penetration of relatively high-consumption sports utility vehicles will support higher oil demand in this sector. It is not expected that diesel will surpass or substitute for gasoline as the primary passenger fuel, as it has in Western Europe. Oil use in the electric power sector is expected to continue its long-term decline as natural-gas-fired generating capacity gains market share. Industrial oil demand is also expected to rise at a modest rate of 1.1 percent per year, reflecting slower growth in industrial output and a continuing structural shift toward less energy-intensive manufacturing and services [***7***].

In Canada, virtually all the increase in oil consumption expected from 1999 to 2020, estimated at 0.5 million barrels per day, is expected to occur in the transportation sector. Canada's extensive hydroelectric and natural gas resources are widely used for power generation and for industrial and commercial uses. The trend in transport fuel demand is similar to that in the United States. Gasoline is the preferred vehicle fuel in the Canadian market, and sales of sport utility vehicles are rising.

In Mexico, total demand for oil is expected to rise by 4.1 percent per year from 1999 to 2020, sustained by an upsurge in the consumption of oil products in all economic sectors, except for power generation. Transportation is expected to remain the largest consumer of oil products, accounting for 50 percent of total petroleum demand in 2020. Total demand for oil is expected to more than double over the forecast period, rising from 2.0 million barrels per day in 1999 to 4.6 million barrels per day in 2020, due mainly to economic growth and a rapidly expanding population.

Western Europe

Oil is the largest energy source in Western Europe; however, the growth in demand projected for the region is the lowest in the *IEO2002* forecast. Oil use in Western Europe is projected to increase by about 0.6 percent per year, from 13.9 million barrels per day in 1999 to 15.8

million barrels per day in 2020. Most of the incremental demand is expected in the transportation sector.

The oil share of the electricity generation market is expected to continue to decline with the rapid penetration of natural gas in the power sector. At current oil prices, heavy fuel oil is too expensive for normal baseload generation, and its main use is in delivering power at peak periods from existing oil-fired boilers. Because cheaper natural gas has become available in the Southern part of Europe through the Trans-Mediterranean pipeline from North Africa (completed in 1983) and the Algerian Bazoduc Maghreb-Europe pipeline to Spain (completed in 1996) [***8***], oil's share of the power generation market is expected to continue to decline [***9***].

Jet fuel demand in Western Europe has increased by 40 percent since 1990, and demand for diesel fuel has risen by more than one-third. Over the same period, gasoline demand has barely changed, mainly because it continues to be more highly taxed than are other fuels, and tax differentials have encouraged consumers to purchase diesel-fueled cars. In addition, the steady growth in road freight is expected to boost diesel demand, assuming that diesel fuel continues to be taxed less heavily than gasoline.

Industrialized Asia

All the countries of industrialized Asia (Japan, Australia, and New Zealand) are net importers of oil. Japan, which imports all the oil it uses, accounts for 81 percent of the total demand in the region. Oil demand in industrialized Asia is projected to increase by an average of 0.9 percent per year, from 6.9 million barrels per day in 1999 to more than 8.3 million barrels per day in 2020. Relative to other fuels, oil use is expected to grow slowly. Oil's share in the region's energy mix is declining steadily with a continuing shift toward other fuels, particularly to natural gas in the power sector. Oil use produces 18 percent of Japan's electricity, and its share has been declining. Australia's use of oil for electricity generation is marginal, and New Zealand uses none [***10***].

Most of the demand for oil in industrialized Asia is for transportation. In Japan, demand for gasoline continues to rise, in large part because of deregulation of the market. Retail gasoline prices in 2001, on average, remained below the levels of 1996, when the Japanese market was liberalized and competition intensified [***11***].

Eastern Europe and the Former Soviet Union

After the collapse of the Soviet Union in 1991 oil demand fell steadily, from 8.3 million barrels per day to approximately 3.7 million barrels per day in 1999. However, economic prospects in the region have improved since 2000, and economic growth is expected for the countries of the FSU in the near future. FSU oil consumption is expected to increase at an annual average rate of 3.7 percent from 1999 to 2020, reaching 8.0 million barrels per day at the end of the forecast period—still well below the region's peak use of 9.0 million barrels per day in 1987.

All the FSU economies began to show positive economic growth in 2000, many of them at high rates. Economic growth in the region is expected to average 4.7 percent per year from 1999 to 2020, but improved industrial efficiencies and fuel switching in favor of natural gas for power generation are projected to result in somewhat slower increases in oil demand, averaging 3.7 percent per year over the forecast.

Oil demand in Eastern Europe is expected to grow by an average of 1.8 percent per year, from 1.5 million barrels per day in 1999 to 2.1 million barrels per day in 2020. Given the expectations for continued economic growth and the accompanying rise in personal income levels, most of the growth in East European oil use is expected to occur in the transportation sector, particularly in the region's largest economies—Poland, Hungary, and the Czech Republic—which are close to Western European markets and are members of the Organization for Economic Cooperation and Development (OECD).

Motorization levels in Eastern Europe (the number of vehicles per thousand persons) are expected to rise from 217 in 1999 to 284 in 2020. Growth in demand for transportation fuels is expected to be led by diesel, as is also expected for the neighboring countries of the European Union. In fact, as part of their drive to join the European Union and meet its fuels standards, major Eastern European refiners such as Poland's PKN Orlen and the Czech Republic's Czeska Rafinerska are continuing to invest heavily in improvements aimed at achieving fuel standards required by the European Union. PKN Orlen, for example, is planning to invest $250 million at its Plock refinery to improve gasoline and diesel quality to meet 50 parts per million sulfur specifications before 2005. This investment is on top of the $2 billion spent on a major refinery upgrade project in 2000 [***12***].

Developing Asia

China

Developing Asia remains the focus of expectations for future growth in world oil demand. In less than 10 years, China is expected to become the largest oil consumer in Asia, surpassing Japan as the world's second largest oil consumer after the United States. With the transportation sector accounting for most of the increase, oil use in China is expected to grow by 4.3 percent per year, from 4.3 million barrels per day in 1999 to 10.5 million barrels per day in 2020 (as compared with 6.4 million barrels per day projected for Japan in 2020).

Currently, the transportation sector is the smallest final energy consumer in China among the major economic sectors, accounting for 14 percent of total energy use. Within the transportation sector, motor fuels consumption accounts for around 70 percent [***13***]. Vehicle ownership, still relatively low in China at less than 12 cars per thousand persons in 1999, is projected to reach 52 per thousand by 2020. As per capita income rises, the demand for cars, and therefore for transport fuel, is expected to increase dramatically. The Chinese government has allocated more resources to expand and upgrade the highway network in anticipation of this growth. By 2020, demand for transportation fuels is projected to make up 56 percent of total oil demand in China. Increasing personal wealth and higher average incomes in China are expected to outweigh high retail prices for transportation fuels, which still are set by the Chinese government but increasingly have reflected global market prices.

Outside the transportation sector, oil demand in China is projected to increase by an average of 2.4 percent per year, as compared with the average growth rate of 0.5 percent per year projected for nontransportation oil use in the industrialized countries. In the 1970s, China consumed a large volume of crude oil directly in various industries, especially for power generation. In the late 1970s, when crude oil production became stagnant, the government moved to restrict the use of oil in the electric power sector and to convert as many oil-fired power plants to coal firing as possible [***14***]. Consumption of petroleum products in China grew by 3.2 percent per year on average during the 1980s and by 6.5 percent per year from 1990 to 1999.

India

India is projected to be among the world's fastest growing economies over the forecast period, and its oil consumption is projected to grow by 4.6 percent per year on average from 1999 to 2020, to nearly 4.9 million barrels per day. The country depends on oil for about 33 percent of its total energy needs and imports about 1.3 million barrels per day or two-thirds of its crude oil requirement.

The transportation sector is expected to be the main source of the increase in India's oil demand over the next two decades. Fuel use for road travel is heavily weighted toward diesel fuel, and approximately 80 percent of motor vehicles in India run on diesel (compared to 15 percent in China). Despite substantial increases in crude oil prices from 2000 through early 2001, diesel remains less than half as expensive as gasoline. India's domestic price deregulation will likely support growth in gasoline demand if it proceeds as scheduled in 2002, with prices expected to fall to import parity levels.

India's agricultural sector is a large consumer of oil products, mainly distillate, although droughts like the one experienced in 1999 have tended to dampen oil demand. Assuming normal precipitation in India, agricultural activity is expected to increase, leading to faster growth in demand for oil in this sector.

Other Developing Asia

Although demand for oil products in developing Asia recovered more rapidly than many analysts expected after the economic crisis of 1997-1999, it is anticipated that, over the long term, oil demand will increase at a slower and more sustainable rate than the high growth rates recorded during the 1990s. The short-term economic outlook and oil demand growth remain mixed, given the current weakness of the export-oriented economies such as South Korea, Taiwan, Singapore, Malaysia, Thailand, Indonesia, and the Philippines. Recovery is expected to be in line with the U.S. economy in the next few quarters.

In 2001, naphtha demand increased rapidly as sizable expansions in naphtha-cracking ethylene production capacities took place in Taiwan and Singapore. To meet this growing demand, ExxonMobil constructed an 800,000 metric ton per year ethylene production unit in Singapore, which became fully operational at the end of 2001. In addition, a combined increment of 280,000 metric tons per year in capacity was scheduled for completion in Singapore and Thailand by the end of 2001 [***15***].

Demand for residual fuel is expected to remain sluggish among the countries of other developing Asia. Power generation and industrial plants are likely to continue shifting away from residual fuel in favor of natural gas. The shutdown of Indonesia's natural gas fields in North Aceh in response to domestic insurgency, however, increased concerns over the stability of the natural gas supply to industries that have switched from oil and have become highly dependent on liquefied natural gas (LNG). South Korea, which currently imports about 42 percent of its LNG from Indonesia [***16***], would be particularly vulnerable to a disruption of LNG supplies.

Total oil demand in South Korea is projected to grow from 2.0 million barrels per day in 1999 to 3.0 million barrels per day in 2020—an average annual rate of 1.9 percent—led by growth in the transportation and industrial sectors. The rate of increase in oil demand is expected to be much slower than it was over the past two decades. Oil demand grew by more than 8 percent per year between 1980 and 1999, as transportation energy use increased rapidly. The main factors that are expected to slow the growth of oil use in the future are moderating economic growth, industrial restructuring, and energy demand saturation in some sectors, particularly transportation. As the Korean economy moves from

energy-intensive industrial activities to service industries, energy intensity is also projected to decline [**17**].

Central and South America

Oil consumption in Central and South America is projected to increase from 4.7 million barrels per day in 1999 to 8.8 million barrels per day in 2020. At present, oil consumption in Central and South America accounts for about 48 percent of total primary energy demand. However, oil's share of the energy mix has been steadily declining, mainly in the power generation and industrial sectors due to substitution of hydroelectricity, natural gas, and coal. Continued declines in oil's share in these sectors are expected to be offset by growth in the transportation sector.

Oil consumption for transportation in Central and South America is expected to increase at an average rate of 3.1 percent per year, from 2.6 million barrels per day in 1999 to 4.9 million barrels per day in 2020. The number of vehicles per thousand people is projected to increase from 100 in 1999 to 236 by 2020.

Brazil is the largest economy in Central and South America, accounting for 42 percent of the region's total oil demand. Brazil's oil consumption in 1999 is estimated to have been 2.0 million barrels per day, the same as India's, and it is projected to grow at an annual average rate of 3.3 percent to 3.9 million barrels per day in 2020.

Brazil's electricity capacity shortage in 2000—caused by a persistent drought that reduced hydroelectric reservoir levels substantially—led to rationing in June 2001. In response to the lack of hydroelectric capacity available, some industrial consumers began to use backup diesel generation to avoid shutting down plants. Brazil's state-owned oil company, Petrobras, announced that it would increase oil imports by 20 percent, from 115,000 barrels per day to 140,000 barrels per day, in order to keep up with the new power-related demand [**18**].

Middle East

Oil dominates the energy mix because of its abundance in the Middle East. After the collapse of oil prices in 1998, economic activities and energy demand in the region were constrained. Low oil prices reduced economic growth in most of the region, particularly Iran and the United Arab Emirates. Saudi Arabia's economy managed to expand but at a slow pace. The impact of lower world oil prices in mid- to late 2001, combined with the economic slowdown led by the United States, kept oil use from expanding in 2001, and demand in the region is expected to be flat in 2002. However, as the world's economies recover and oil demand returns in the industrialized world, so too should growth in Middle East oil use. Oil consumption in the Middle East is projected to grow by 2.1 percent per year, from 5.0 million barrels per day in 1999 to 7.8 million barrels per day in 2020.

Oil demand growth in the Middle East is driven by the transportation sector, particularly in countries with large populations, such as Turkey and Iran. The growing petrochemical sectors of Saudi Arabia and the United Arab Emirates are another explanation for the increase in oil use in the region.

Africa

Oil currently supplies 44 percent of Africa's total energy needs. Demand for oil in the region is projected to grow by 3.6 percent per year, from 2.5 million barrels per day in 1999 to 5.3 million barrels per day in 2020. The transportation and electric power sectors, and to a lesser degree the residential sector, account for most of the region's oil consumption. About 47 percent of Africa's total oil use in 1999 was for transportation, and oil demand in the region's transportation sector is expected to grow by an average of 3.1 percent per year, to 2.2 million barrels per day in 2020.

Oil is widely used for electricity generation in Africa, with the exception of South Africa which has huge domestic coal deposits. In the second half of the forecast period, natural gas is expected to start to make some inroads in the electricity sector as African countries develop natural gas infrastructures [**19**]. In addition, oil is still important for agricultural activities in many African economies.

The impact of the high oil price environment in 2000 and at the beginning of 2001 was lower demand in South Africa, the largest economy in the region, as well as in many small, oil-importing countries. However, most of the continent's key economies, including Egypt, Nigeria, Algeria, and Libya, export oil and continue to boost their revenues and consequently economic growth and oil use [**20**].

The Composition of World Oil Supply

In the *IEO2002* reference case, world oil supply in 2020 is projected to exceed the 2000 level by 41 million barrels per day. Increases in production are expected for both OPEC and non-OPEC producers; however, only about one-third 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.

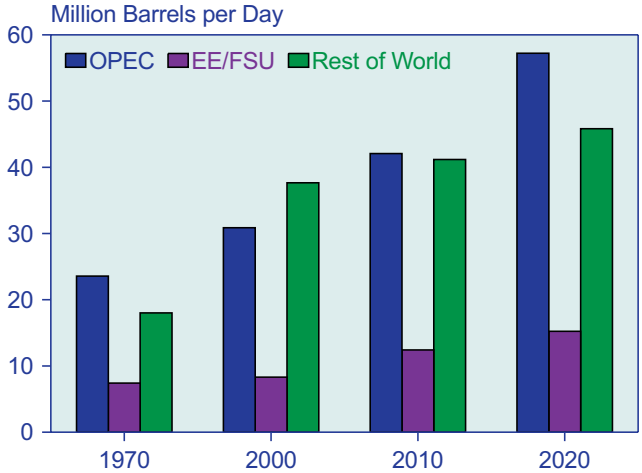
While the long-term outlook for non-OPEC supply remains optimistic, the low oil price environment of 1998 and early 1999 had a definite impact on exploration and development activity. By the end of 1998, drilling activity in North America had fallen by more than 25 percent from its level a year earlier. 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 [***21***].

The reference case projects that about two-thirds 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 2020 is projected to be more than 26 million barrels per day higher than it was in 2000 (Figure 28). The *IEO2002* estimates of OPEC production capacity to 2005 are slightly less than those projected in *IEO2001*, 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 8 shows estimates of the conventional oil resource base by region out to the year 2025, based on the *World Petroleum Assessment 2000* by the U.S. Geological Survey (USGS). The oil resource base is defined by three categories: remaining reserves (oil that has been discovered but not produced); reserve growth (increases in reserves resulting mainly from technological factors that enhance a field's recovery rate); and undiscovered (oil that remains to be found through exploration). The information in Table 8 is derived from the USGS mean estimate, an average assessment over a wide range of uncertainty for reserve growth and undiscovered resources. The *IEO2002* oil production forecast is based on the USGS mean assessment.

Figure 28. World Oil Production in the Reference Case by Region, 1970, 2000, 2010 and 2020



Sources: **History:** Energy Information Administration (EIA), *International Petroleum Monthly*, DOE/EIA-0520(2001/11) (Washington, DC, November 2001). **Projections:** EIA, World Energy Projection System (2002).

Expansion of OPEC Production Capacity

It is generally acknowledged that OPEC members with large reserves and relatively low costs for expanding production capacity can accommodate sizable increases in petroleum demand. In the *IEO2002* reference case, the production call on OPEC suppliers is projected to grow at a robust annual rate of 3.3 percent through 2020 (Table 9 and Figure 29). OPEC capacity utilization is expected to increase sharply after 2000, reaching 95 percent by 2015 and remaining there for the duration of the projection period.

Table 8. Estimated World Oil Resources, 2000-2025
(Billion Barrels)

Region and Country	Proved Reserves	Reserve Growth	Undiscovered
Industrialized			
United States	30.48	76.03	83.03
Canada	15.46	12.48	32.59
Mexico	35.48	25.63	45.77
Japan	0.15	0.09	0.31
Australia/New Zealand	4.34	2.65	5.93
Western Europe	23.77	19.32	34.58
Eurasia			
Former Soviet Union	63.56	137.70	170.79
Eastern Europe	2.40	1.46	1.38
China	24.00	19.59	14.62
Developing Countries			
Central and South America	99.86	90.75	125.31
India	6.24	3.81	6.78
Other Developing Asia	16.51	14.57	23.90
Africa	80.46	73.46	124.72
Middle East	702.69	252.51	269.19
Total	**1,105.41**	**730.05**	**938.90**
OPEC	**863.29**	**395.57**	**400.51**
Non-OPEC	**242.12**	**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.

Iraq's role in OPEC in the next several years will be of particular interest. In 1999, Iraq expanded its production capacity to 2.8 million barrels per day in order to reach the slightly more than $5.2 billion in oil exports allowed by United Nations Security Council resolutions. The expansion was required because of the low price environment of early 1999. In the *IEO2002* reference case, Iraq is assumed to maintain its current oil production capacity of 3.1 million barrels per day into 2002, and its exports are assumed to generate revenues no greater than those allowed by the United Nations Security Council sanctions. Iraq has indicated a desire to expand its 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, including France, Russia, and China. Such a significant increase in Iraqi oil exports would offset a significant portion of the price stimulus associated with current OPEC production cutbacks.

Given the requirements for OPEC production capacity expansion implied by the *IEO2002* estimates, much attention has been focused on the oil development, production, and operating costs of individual OPEC producers. With Persian Gulf producers enjoying a reserve-to-production ratio that exceeds 86 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 $5,500 [***22***]. Assuming the *IEO2002* 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 23 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 $12,000 in some member nations; yet those producers can expect margins in excess of 32 percent on investments to expand production capacity over the long term, even in the low price case [***23***]. Venezuela has the greatest potential for capacity expansion and could aggressively increase its production capacity by more than 1.1 million barrels per day, to 4.2 million barrels per day by 2005. It is unclear, however, whether the current political climate will support the outside investment required for any substantial expansion of production capacity. Tables D1-D6 in Appendix D show the ranges of production potential for both OPEC and non-OPEC producers.

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

In the *IEO2002* 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

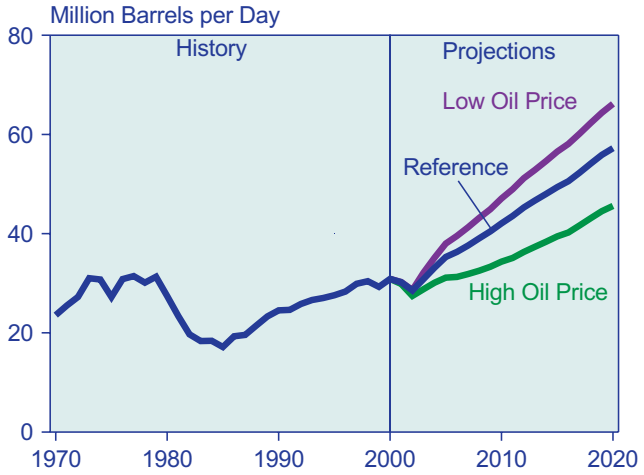
Table 9. OPEC Oil Production, 1990-2020
(Million Barrels per Day)

Year	Reference Case	High Oil Price	Low Oil Price
History			
1990	24.5	—	—
2000	30.9	—	—
Projections			
2005	35.3	31.1	38.0
2010	42.1	34.3	47.1
2015	49.4	39.4	56.5
2020	57.2	45.6	66.2

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

Sources: **History:** Energy Information Administration (EIA), *International Petroleum Monthly*, DOE/EIA-0520(2001/11) (Washington, DC, November 2001), Table 1.4. **Projections:** EIA, World Energy Projection System (2002).

Figure 29. OPEC Oil Production in Three Oil Price Cases, 1970-2020



Sources: **History:** Energy Information Administration (EIA), *International Petroleum Monthly*, DOE/EIA-0520(2001/11) (Washington, DC, November 2001). **Projections:** EIA, World Energy Projection System (2002).

production potential of Algeria, Libya, and Venezuela supports the possibility of reducing the world's dependence on Persian Gulf oil.

Non-OPEC Supply

The growth in non-OPEC oil supplies played a significant role in the erosion of OPEC's market share over the past 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 *IEO2002* reference case, non-OPEC supply from proven reserves is expected to increase steadily, from 46.0 million barrels per day in 2000 to 61.1 million barrels per day in 2020 (Table 10).

There are several important differences between the *IEO2002* production profiles and those published in *IEO2001*:

- The U.S. production decline is considerably less severe in the *IEO2002* projections as a result of higher oil price paths, technological advances yielding higher recovery rates, and lower costs for deep exploration and production in the Gulf of Mexico.
- The estimated peak for North Sea production is delayed by a year to 2006 in the *IEO2002* forecast, and the expected decline in production to 2020 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 *IEO2001* forecast due to significant geopolitical challenges and an expected lower price environment. In the *IEO2002* projections, Caspian output is expected to rise to almost 3 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.
- *IEO2001* 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 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 *IEO2002* forecast by 2 to 3 years (see box on page 35).

In the *IEO2002* forecast, North Sea production reaches a peak in 2006, at almost 6.7 million barrels per day. 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 3.0 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 2.7 million barrels per day by the middle of this decade, followed by a decline to 2.5 million barrels per day by 2020.

Two non-OPEC Persian Gulf producers are expected to increase output gradually for the first half of this decade. Enhanced recovery techniques are expected to increase current output in Oman by more than 180,000 barrels per day, with only a gradual production decline anticipated after 2005. Current oil production in Yemen is expected to increase by at least 110,000 barrels per day within the next couple of years, and those levels should show little decline throughout the forecast period. Syria is expected to hold its production flat through the first half of 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, production is expected to reach almost 240,000 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 425,000 barrels per day by 2020.

Table 10. Non-OPEC Oil Production, 1990-2020
(Million Barrels per Day)

Year	Reference Case	High Oil Price	Low Oil Price
History			
1990	42.2	—	—
2000	46.0	—	—
Projections			
2005	49.6	51.7	48.9
2010	53.6	58.1	52.2
2015	57.8	63.7	55.7
2020	61.1	68.2	58.7

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

Sources: **History:** Energy Information Administration (EIA), *International Petroleum Monthly*, DOE/EIA-0520(2000/11) (Washington, DC, November 2001), Table 1.4. **Projections:** EIA, World Energy Projection System (2002).

The 21st Century's First Non-OPEC Surprise: The Atlantic Basin

Non-OPEC oil production has always shown amazing resiliency in the face of overt pessimism. Words such as "decline" and "stagnation" have frequently been associated with forecasts of long-term non-OPEC supply potential. However, the year 2000 saw non-OPEC producers achieve output volumes of almost 46 million barrels per day after two decades of steady growth that averaged 1.1 percent annually.[a] Two factors are generally given credit for non-OPEC's dependable growth. First, the evolution of exploration and recovery technologies dramatically reduced costs and allowed the exploitation of more hostile environments. 3-D seismic, horizontal drilling, floating platforms, and sub-sea completion systems are just some of the technologies that have made important contributions. Second, a few non-OPEC surprises have always seemed to surface every decade. Over the past 25 years, the Alaskan North Slope, Mexico, the North Sea, and the Caspian Basin all have qualified as surprises, with oil production potential exceeding expectations.

A rebound in oil prices from the extremely low levels of 1998 and early 1999 ushered in the new century. The increased drilling activity brought about by higher prices produced an obvious candidate for the first non-OPEC surprise of the 21st century. The Atlantic Basin, featuring Brazil and Argentina along coastal Latin America and the countries from Mauritania to Namibia along coastal West Africa, was experiencing oil finds that were both frequent and sizable. As with many of the non-OPEC surprises of the past, most of this oil was being found in hostile environments. In this case, it was offshore fields in water depths that tested exploration and recovery technologies to their limits.

Most of the interest in the Latin American offshore sector is focused on Brazil. Many of the significant developments in deepwater exploration and production have evolved in Brazil. As early as the 1970s, Brazil recognized the need to concentrate its exploration efforts in offshore areas. The initial production from an offshore basin started in 1977. Its ventures into ultra-deep projects have claimed several world records. Brazil has also realized that two-thirds of the prospective global offshore basins lie in extremely deep water. It is estimated that 75 percent of Brazil's total reserves couldcome from ultra-deepwater projects, exceeding 3,000 feet. Industry experts expect that water depths exceeding 8,000 feet will most likely be feasible for production purposes within 5 years.

In 1997, Brazil enacted legislation that allowed private-sector participation in oil exploration, production, refining, and distribution. As a result of this decision and the resulting diversity and expertise of the investors in Brazil's oil sector,[b] the country's long-term oil exploration and production outlook is viewed with optimism. In the *IEO2002* forecast, Brazil's oil production is expected to increase to 2.8 million barrels per day by 2010, more than doubling current levels. By 2020, production is projected to reach 4.1 million barrels per day. It is expected that the entirety of Brazil's oil production will be consumed domestically, leaving only a modest requirement for imports.

Most of the non-OPEC interest in the West African offshore sector is centered on Angola. Over the past 3 years, the success rate of exploration wells in Angola's deepwater blocks has been stunning, and the field sizes are proving to be astonishing. More than a dozen fields, each with reserves totaling more than 500 million barrels, are being readied for near- to mid-term development. Capital investment in the Angolan oil sector has eclipsed even OPEC member Nigeria's investment draw. In 2000, the offshore sector provided 40 percent of Angola's gross domestic product.

The prolific nature of Angola's oil field discoveries has brought the region to the forefront as the cutting edge for new deepwater technologies. As with many of the West African states, Angola offers attractive terms and conditions with less costly operations than other offshore provinces.[c] *IEO2002* projects that Angola's oil production will increase to levels of 2.1 million barrels per day by 2010, almost tripling current levels, and to 3.3 million barrels per day by 2020. There is a long-term strategic value to Angolan crude oil supplies that should not be underestimated. Many West African streams are lighter, higher-valued crude oils that are tailor-made for U.S. East Coast markets and are able to offer an alternative to Middle Eastern supply sources.

While Brazil and Angola are the Atlantic Basin's predominant non-OPEC oil producers, other emerging economies are also positioned to capture a slice of the deepwater action. In Latin America, Argentina is projected to become a 1 million barrel per day producer by the end of this decade with the development of its offshore sector. In Africa, just about every West African country is either conducting its own search for hydrocarbons or attempting to attract outside investors for licensing agreements. Those countries displaying a

(continued on page 36)

[a]Energy Information Administration, *International Petroleum Monthly*, DOE / EIA-0520(2001 / 12) (Washington, DC, December 2001).

[b]"Deepwater at the Double," *Hart's E&P*, Vol. 73, No. 10 (October 2000), p. 40.

[c]"World Focus on West Africa," *Hart's E&P*, Vol. 74, No. 1, Supplement (January 2001), p. 3.

Australia has made significant recent additions to its proven reserves, and it is possible that Australia will become a 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 650,000 barrels per day by 2020. Papua New Guinea continues to add to its reserve posture and is expected to achieve production volumes approaching 200,000 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 Mongolia, 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 2.5 million barrels per day by 2020. Colombia's current economic downturn and civil unrest have delayed its bid to join the relatively short list of worldwide million barrel per day producers, but its output is expected to top a million barrels per day within the decade and show 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 likely to become a million barrel per day producer. Although the current political situation in Ecuador is in transition, there is still optimism that Ecuador will increase production by more than 300,000 barrels per day within the next couple of 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 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 360,000 barrels per day for the duration of the forecast.

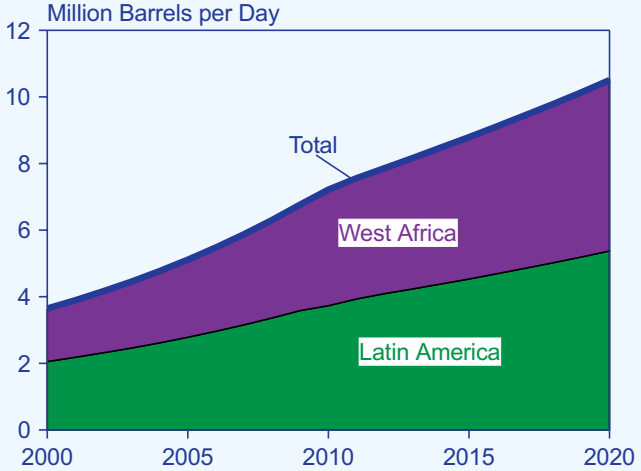
North African producers Egypt and Tunisia produce mainly from mature fields and show little promise of adding to their reserve posture. As a result, their production volumes are expected to decline gradually throughout the forecast. Sudan and Equatorial Guinea are expected to produce modest volumes early in this decade. Eritrea, Somalia, and South Africa also have some resource potential, but they are not expected to produce significant amounts until after 2005.

The 21st Century's First Non-OPEC Surprise: The Atlantic Basin (Continued)

particular interest in deepwater projects include the Ivory Coast, Sierra Leone, Equatorial Guinea, Congo, Namibia, and Gabon. The figure at right presents the oil production forecast for Atlantic Basin non-OPEC producers out to 2020.

There is one particularly attractive aspect of the deepwater component of the oil industry: it is a sector that is still in its infancy. Of the deepwater oil that has been discovered, only 20 percent has been developed and produced. Excursions into water depths over 5,000 feet are still relatively rare and are considered on the edge of feasibility. However, such barriers are softening with the willingness and confidence of oil companies in tackling deepwater projects. Companies are beginning to realize that the deepwater sector is likely to mature over a substantial number of years, and it therefore represents an integral part of their future business for a long time to come. With the exception of Nigeria, most deepwater areas are outside OPEC boundaries. This can only be considered an unexpected but welcome bonus for the deepwater niche of the non-OPEC world oil market.

Projected Atlantic Basin Non-OPEC Oil Production, 2000-2020



Source: Energy Information Administration, World Energy Projection System (2002).

In North America, moderately rising U.S. output is expected to be complemented by significant production increases in Canada and Mexico. Canada's 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 700,000 barrels per day in output from a combination of frontier area offshore projects and oil from tar sands. 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 encourage the efficient development of its vast resource base. Expected production volumes in Mexico exceed 4.1 million barrels per day by the end of the decade and remain near that level through 2020.

With assumed higher oil prices, oil production in the FSU is expected to reach 10.0 million barrels per day by 2005—a level that could be somewhat higher if the outlook for investment in Russia were not so pessimistic. The long-term production potential for the FSU is still regarded with considerable optimism, especially for the resource-rich Caspian Basin region. The *IEO2002* reference case shows FSU output exceeding 14.8 million barrels per day by 2020, implying export volumes exceeding 6.9 million barrels per day. In China, oil production is expected to decline by nearly 3.0 million barrels per day by 2020. China's import requirements are expected to be as large as its domestic production by 2010 and to continue growing as its petroleum consumption increases.

The estimates for non-OPEC production potential presented in this outlook are based on such parameters as numbers of exploration wells, finding rates, reserve-to-production ratios, advances in both exploration and extraction technologies, and the 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 *IEO2002* price cases, no more than 15, 25, and 35 percent of the mean United States Geological Survey estimate of non-OPEC undiscovered oil is assumed to be developed over the forecast period in the low, reference, and high price cases, respectively. In all 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 within OPEC countries (especially those in the Persian Gulf region) was considered such an overwhelming advantage that non-OPEC production potential was viewed with considerable pessimism. In actuality, however, despite a relatively low price environment, non-OPEC production has risen every year since 1993, adding more than 5.2 million barrels per day between 1993 and 2000.

It is expected that non-OPEC producers will continue to increase output, producing an additional 7.6 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 2000, industrialized countries imported 15.8 million barrels of oil per day from OPEC producers. Of that total, 9.9 million barrels per day came from the Persian Gulf region. Oil movements to industrialized countries represented more than 70 percent of the total petroleum exported by OPEC member nations and almost two-thirds of all Persian Gulf exports (Table 11). By the end of the forecast period, OPEC exports to industrialized countries are estimated to be about 6.2 million barrels per day higher than their 2000 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 2020 is projected to be almost 14 percent below their 2000 share, and the share of Persian Gulf exports going to the industrialized nations is projected to fall to about 40 percent. The significant shift expected in the balance of OPEC export shares between the industrialized and developing nations is a direct result of the robust economic growth anticipated for the developing nations of the world, especially those of Asia. OPEC petroleum exports to developing countries are expected to increase by more than 17.0 million barrels per day over the forecast period, with more than half of the increase going to the developing countries of Asia. China, alone, is likely to import about 7.2 million barrels per day from OPEC by 2020, virtually all of which is expected to come from Persian Gulf producers.

North America's petroleum imports from the Persian Gulf are expected to almost double over the forecast period (Figure 30). At the same time, more than one-half

of total North American imports in 2020 are expected to be from Atlantic Basin producers and refiners, with significant increases expected in crude oil imports anticipated from Latin American producers, including Venezuela, Brazil, Colombia, and Mexico. West African producers, including Nigeria and Angola, are also expected to increase their export volumes to North America. Caribbean Basin refiners are expected to account for most of the increase in North American imports of refined products.

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 more than double their total petroleum imports between 2000 and 2020.

Worldwide crude oil distillation refining capacity was about 81.5 million barrels per day at the beginning of 2000. To meet the projected growth in international oil demand in the reference case, worldwide refining capacity would have to increase by more than 50 million barrels per day by 2020. Substantial growth in distillation capacity is expected in the Middle East, Central and South America, and especially in the Asia Pacific region.

Table 11. Worldwide Petroleum Trade in the Reference Case, 2000 and 2020
(Million Barrels per Day)

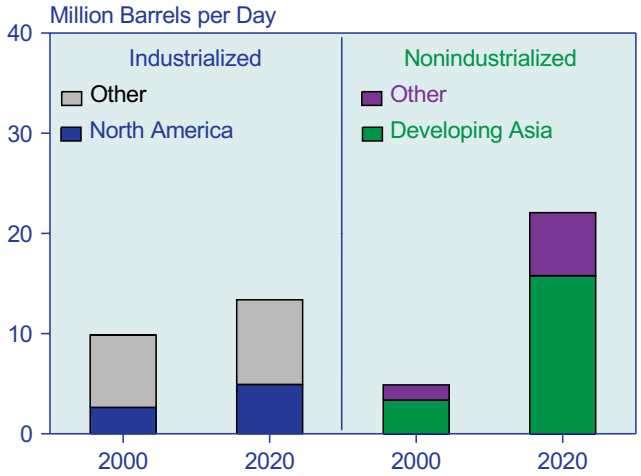
	Importing Region							
	Industrialized				Nonindustrialized			
Exporting Region	North America	Western Europe	Asia	Total	Pacific Rim	China	Rest of World	Total
	2000							
OPEC								
Persian Gulf	2.6	3.2	4.1	**9.9**	2.7	0.7	1.5	**4.9**
North Africa	0.3	2.0	0.0	**2.3**	0.0	0.0	0.1	**0.1**
West Africa	0.9	0.5	0.0	**1.4**	0.1	0.0	0.1	**0.2**
South America	1.6	0.2	0.0	**1.8**	0.1	0.0	0.8	**0.9**
Asia	0.1	0.0	0.3	**0.4**	0.2	0.0	0.0	**0.2**
Total OPEC	**5.4**	**5.9**	**4.5**	**15.8**	**3.2**	**0.7**	**2.5**	**6.4**
Non-OPEC								
North Sea	0.6	4.7	0.0	**5.3**	0.0	0.0	0.0	**0.0**
Caribbean Basin	1.8	0.2	0.0	**2.1**	0.3	0.0	2.2	**2.5**
Former Soviet Union	0.0	1.6	0.0	**1.7**	0.2	0.0	0.1	**0.3**
Other Non-OPEC	2.9	1.3	0.9	**5.1**	1.9	0.4	1.1	**3.4**
Total Non-OPEC	**5.3**	**7.8**	**1.0**	**14.1**	**2.4**	**0.4**	**3.4**	**6.2**
Total Petroleum Imports	**10.7**	**13.7**	**5.4**	**29.9**	**5.6**	**1.1**	**5.9**	**12.5**
	2020							
OPEC								
Persian Gulf	4.9	3.5	5.0	**13.4**	8.7	7.1	4.3	**20.1**
North Africa	0.5	2.3	0.0	**2.7**	0.1	0.0	0.4	**0.6**
West Africa	0.9	0.9	0.2	**2.0**	0.1	0.0	0.9	**1.0**
South America	3.3	0.3	0.1	**3.7**	0.1	0.0	1.4	**1.5**
Asia	0.1	0.0	0.1	**0.2**	0.2	0.1	0.0	**0.3**
Total OPEC	**9.7**	**6.9**	**5.5**	**22.0**	**9.3**	**7.2**	**7.0**	**23.4**
Non-OPEC								
North Sea	0.5	3.9	0.0	**4.4**	0.1	0.0	0.0	**0.1**
Caribbean Basin	3.4	0.4	0.1	**3.9**	0.2	0.0	1.5	**1.6**
Former Soviet Union	0.4	3.1	0.5	**4.0**	1.4	0.1	0.2	**1.7**
Other Non-OPEC	4.2	1.3	0.4	**5.9**	2.2	0.3	1.2	**3.7**
Total Non-OPEC	**8.4**	**8.8**	**1.0**	**18.2**	**3.9**	**0.4**	**2.9**	**7.2**
Total Petroleum Imports	**18.2**	**15.6**	**6.5**	**40.3**	**13.1**	**7.6**	**9.9**	**30.6**

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

Sources: **2000:** Energy Information Administration (EIA), Energy Markets and Contingency Information Division. **2020:** EIA, Office of Integrated Analysis and Forecasting, IEO2002 WORLD Model run IEO2002.B20 (2002).

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.

Figure 30. Imports of Persian Gulf Oil by Importing Region, 2000 and 2020



Sources: **2000:** Energy Information Administration (EIA), *International Petroleum Monthly*, DOE/EIA-0520(2001/11) (Washington, DC, November 2001). **2020:** EIA, Office of Integrated Analysis and Forecasting, IEO2002 WORLD Model run IEO2002.B20 (2002).

Other Views of Prices and Production

Several oil market analysis groups produce world oil price and production forecasts. Table 12 compares the *IEO2002* world oil price projections with similar forecasts from the International Energy Agency (IEA), Petroleum Economics, Ltd. (PEL), Petroleum Industry Research Associates (PIRA), the Gas Research Institute (GRI), Natural Resources Canada (NRCan), DRI-WEFA, 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 sent upward by 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.

Table 12. Comparison of World Oil Price Projections, 2005-2020
(2000 Dollars per Barrel)

Forecast	2005	2010	2015	2020
IEO2002				
Reference Case	22.73	23.36	24.00	24.68
High Price Case	29.56	30.01	30.44	30.58
Low Price Case	17.41	17.64	17.64	17.64
DRI-WEFA (October 2001)	19.39	20.32	21.81	23.12
IEA (November 2000)	20.41	20.41	—	27.83
PEL (June 2001)	13.53	14.77	13.38	—
PIRA (October 2001)	24.31	24.21	27.75	—
GRI (March 2001)	18.70	18.70	18.70	18.70
NRCan (April 1997)	21.79	21.79	21.79	21.79
DBAB (December 2001)	17.68	17.58	17.95	18.30

Notes: *IEO2001* projections are for average landed imports to the United States. S&P, GRI, WEFA, and DBAB projections are for composite refiner acquisition prices. PEL projections are for Brent crude oil. PIRA projections are for West Texas Intermediate crude oil at Cushing.

Sources: ***IEO2002*:** Energy Information Administration, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001). **DRI-WEFA:** DRI-WEFA, *U.S. Energy Outlook, Spring/Summer 2001* (Lexington, MA, October 2001), p. 49. **IEA:** International Energy Agency, *World Energy Outlook 2000* (Paris, France, November 2000), p. 39. **PEL:** Petroleum Economics, Ltd., *Oil and Energy Outlook to 2015* (London, United Kingdom, June 2001), p. 10. In the 2001 edition of this report, PEL declared two possible oil price projections in 2010 and 2015 (neither of which was identified as a "base case"). In 2010, either 13.53 or 18.06 and in 2015, either 13.38 or 16.35 depending on OPEC behavior. **PIRA:** PIRA Energy Group, *Retainer Client Seminar* (New York, NY, October 2001), Table II-3. **GRI:** Gas Research Institute, *Baseline Projection Data Book 2001 Edition*, Volume I, p. SUM-21 (March 2001), crude oil (refiner acquisition). **NRCan:** Natural Resources Canada, *Canada's Energy Outlook, 1996-2020*, Annex C2 (Ottawa, Ontario, Canada, April 1997) (reaffirmed in January 2000). **DBAB:** Deutsche Banc Alex.Brown, Inc., "World Oil Supply and Demand Estimates," e-mail from Adam Sieminski (December 14, 2001).

Given the uncertainties of the current world situation, there is a spread of more than $10 per barrel among the forecasts for oil prices in 2005, as compared with the spread of only $6 per barrel among the forecasts available last year. The current oil price projections for 2005 range from PEL's $13.53 per barrel (constant 2000 U.S. dollars) to PIRA's $24.21 per barrel. The NRCan and IEA forecasts are the earliest: NRCan's projection was formulated in 1997 (but reaffirmed in 2000) and IEA's in November 2000. Nevertheless, those forecasts fall well within the range defined by the other forecasts. Two of the forecasts, PEL and DBAB, fall below the range defined by the *IEO2002* high and low world oil price scenarios in 2005, again demonstrating the wide range of projections in the early years of the forecast.

IEO2002 expects oil prices to rise to $23.15 in 2005. This projection leans somewhat toward the higher end of the forecasts: only PIRA projects higher world oil prices in 2005. Recent forecasts from DRI-WEFA, DBAB, and GRI all expect that prices will be in the range of $18 to just under $20 per barrel in 2005.

The entire PEL price forecast series may be considered an outlier relative to the rest of the forecasts. PEL's price projections fall consistently below those of the *IEO2002* 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, $10 per barrel, with PIRA at the high end of the range ($27.75 per barrel) and DBAB at the low end ($17.95 per barrel). At the end of the forecast period, the uncertainty among forecasters as measured by the difference between highest and lowest expected prices remains about the same at $9.53 per barrel in 2020.

IEO2002 prices are the highest of any of the series across the 2005-2020 time period, with the exception of PIRA between 2005 and 2015 and IEA in 2020. It should be noted that IEA did not publish a price projection for 2015 in its *World Energy Outlook 2000*; however, it states that "between 2010 and 2020, the price increases steadily," from $20.41 per barrel to $27.83 per barrel. A simple interpolation results in an oil price in 2015 of about $24.12 per barrel, placing the IEA price very close to (but still below) the *IEO2002* estimate of $24.45 per barrel.

The price forecasts are influenced by differing views of the projected composition of world oil production. Two factors are of particular importance: (1) expansion of OPEC oil production and (2) the timing of a recovery in EE/FSU oil production. All the 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.

Higher world oil prices in 2000 and the early part of 2001, along with accelerating economic recovery in Russia, currently the largest oil producer in the 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 13 percent over the course of the projection period. DBAB estimates that EE/FSU production will rise to 16 percent of the world total supply by 2020 (Table 13). DRI-WEFA is the least optimistic about recovery in the region, and its projected share for the EE/FSU remains at 9 percent throughout the 2005-2020 time period. *IEO2002* and PIRA are also optimistic about production in the region. Both forecasts expect the EE/FSU share of world oil production to climb from 12 percent in 2005 to 13 percent in 2010, where it remains for the remainder of the limits of the forecasts (that is, 2015 for PIRA and 2020 for *IEO2002*).

The forecasts that provide projections through 2020 (*IEO2002*, DRI-WEFA, DBAB, and IEA) all expect OPEC to provide incremental production of between 20 and 33 million barrels per day between 1999 and 2020 (Table 13). There is more variation in expectations among these four forecasts for the "other" non-OPEC suppliers. DRI-WEFA expects a substantial increase of 14.3 million barrels per day of supply from other suppliers, whereas IEA expects a decline of 3.4 million barrels per day in production from other non-OPEC sources. IEA projects that the "other" share of world oil production will fall to 29 percent by 2020 while the OPEC share increases to 54 percent. In contrast to DRI-WEFA, *IEO2002* expects more moderate growth in other non-OPEC supply, at 8.6 million barrels per day from 1999 to 2020; DBAB expects growth of 3.3 million barrels per day.

References

1. Energy Information Administration, *Short-Term Energy Outlook*, March 2002 on-line version, web site www.eia.doe.gov/emeu/steo/pub/contents.html.
2. International Energy Agency, *China: Worldwide Quest For Energy Security* (Paris, France, 2000), p. 17.
3. Energy Information Administration, *Short-Term Energy Outlook*, November 2001 and September 2001 editions, web site www.eia.doe.gov/emeu/steo/pub/contents.html.
4. Energy Information Administration, *Short-Term Energy Outlook*, February 2002 edition, web site www.eia.doe.gov/emeu/steo/pub/contents.html.
5. Cambridge Energy Research Associates, "Refining Margins: Back to the Doldrums," *Refined Products Watch, Summer 2001* (Cambridge, MA, July 2001), p. 9.

Table 13. 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							
1999	39	10	50	29.1	7.6	37.2	**73.9**
Projections							
2005							
IEO2002	42	12	46	35.3	10.3	39.8	**84.9**
DRI-WEFA[a]	39	9	48	33.3	7.5	40.9	**85.4**
PEL	39	10	48	32.9	8.8	40.4	**84.0**
PIRA	36	12	52	30.3	10.0	43.4	**83.7**
DBAB	40	13	45	32.3	10.6	36.9	**81.1**
2010							
IEO2002	44	13	43	42.1	12.4	41.2	**95.7**
DRI-WEFA[a]	39	9	48	37.0	8.8	45.2	**90.3**
IEA[b]	46	11	38	44.1	10.3	36.6	**95.9**
PEL	43	10	44	40.2	9.4	41.1	**92.8**
PIRA	38	13	49	35.0	12.1	45.1	**92.2**
DBAB	42	15	41	38.0	13.2	36.9	**90.3**
2015							
IEO2002	46	13	41	49.4	14.0	43.8	**107.2**
DRI-WEFA[a]	41	9	47	42.7	9.8	49.1	**104.9**
PEL	51	10	37	52.4	9.8	37.7	**102.2**
PIRA	41	13	46	41.0	13.3	45.7	**100.0**
DBAB	44	15	39	43.4	15.3	38.4	**99.5**
2020							
IEO2002	48	13	39	57.2	15.3	45.8	**118.3**
DRI-WEFA[a]	43	9	44	50.6	10.8	51.5	**117.2**
IEA[b]	54	11	29	61.8	12.3	33.8	**114.7**
DBAB	45	16	37	49.4	17.7	40.5	**110.3**

[a]In the DRI-WEFA 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, DRI-WEFA, 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: ***IEO2002*:** Energy Information Administration, World Energy Projection System (2002). **DRI-WEFA:** DRI-WEFA, *Oil Market Outlook: Long Term Focus, Second Quarter 2000* (Lexington, MA, 2000), p. 14. **IEA:** International Energy Agency, *World Energy Outlook 2000* (Paris, France, November 2000), p. 77. **PEL:** Petroleum Economics, Ltd., *Oil and Energy Outlook to 2015* (London, United Kingdom, June 2001). **PIRA:** PIRA Energy Group, *Retainer Client Seminar* (New York, NY, October 2001). **DBAB:** Deutsche Banc Alex.Brown, fax from Adam Sieminski (December 14, 2001).

6. Cambridge Energy Research Associates, "World Energy Markets—The Same But Different," *Global Energy Watch, Autumn 2001* (Cambridge, MA, November 2001), p.11.
7. Energy Information Administration, *Annual Energy Outlook 2002*, EIA/DOE-0383(2002) (Washington, DC, December 2001), Table A11.
8. International Institute for Applied Systems Analysis, *The Future of Gas Infrastructures in Eurasia* (Laxenburg, Austria, May 2001), p. 406.
9. Petroleum Economics, Ltd., *Oil and Energy Outlook to 2015* (London, UK, June 2001), p. 32.
10. International Energy Agency, *World Energy Outlook 2000* (Paris, France, November 2000), p. 168.
11. Cambridge Energy Research Associates, "The Check Is in the Mail," *World Oil Watch, Autumn 2000* (Cambridge, MA, October 2000), p. 23.
12. Cambridge Energy Research Associates, "Refining Margins: Back to the Doldrums," *Refined Products Watch, Summer 2001* (Cambridge, MA, July 2001), p. 34.
13. DRI-WEFA, *World Energy Service Asia/Pacific Outlook* (Lexington, MA, April 2001).

14. Fesharaki Associates Consulting & Technical Services (FACTS), Inc., *China's Natural Gas to 2015* (Honolulu-Singapore, October 2000), p. I-21.

15. Cambridge Energy Research Associates, "Refining Margins: Back to the Doldrums," *Refined Products Watch, Summer 2001* (Cambridge, MA, July 2001), p. 23.

16. BP p.l.c., *BP Statistical Review of World Energy 2001* (London, UK, June 2001), web site www.bp.com.

17. Korea Energy Economics Institute, "Long-Term Energy Demand Forecast in Korea," *Korea Energy Review Monthly* (Euiwang-Si, South Korea, June 2001), p. 23.

18. Cambridge Energy Research Associates, "Refining Margins: Back to the Doldrums," *Refined Products Watch, Summer 2001* (Cambridge, MA, July 2001), p. 29.

19. Standard & Poor's DRI, *Oil Market Outlook, Long Term Focus, First Quarter 2001* (Lexington, MA, 2001), web site www.dri-wefa.com.

20. Cambridge Energy Research Associates, "The Check Is in the Mail," *World Oil Watch, Autumn 2000* (Cambridge, MA, December 2000), p. 25.

21. "Offshore Prospects Delayed in Low Price Environment," *Hart's E&P*, Vol. 27, No. 1 (January 1999), p. 40.

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

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

Natural Gas

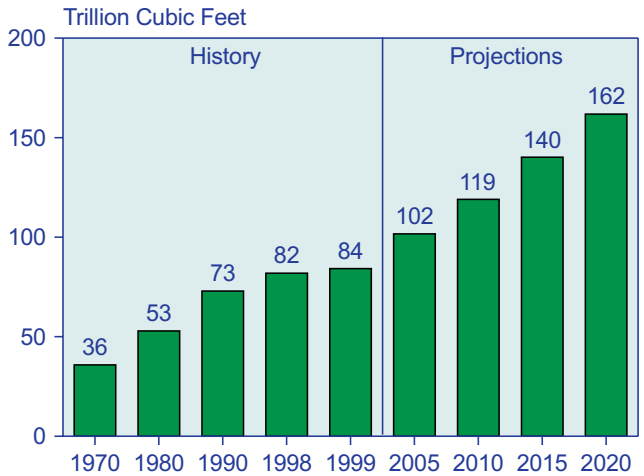
Natural gas is the fastest growing primary energy source in the IEO2002 forecast. The use of natural gas is projected to nearly double between 1999 and 2020, providing a relatively clean fuel for efficient new gas turbine power plants.

Natural gas is expected to be the fastest growing component of world energy consumption in the *International Energy Outlook 2002* (*IEO2002*) reference case. Natural gas consumption in 2020 is projected to total 162 trillion cubic feet, nearly double the 1999 total of 84 trillion cubic feet (Figure 31), and its share of total energy consumption is projected to increase from 23 percent in 1999 to 28 percent in 2020. The growth of natural gas consumption in developing countries (Figure 32) is expected to be significantly greater than in the rest of the world, averaging 5.3 percent per year, as compared with 2.4 percent per year in the industrialized countries, 2.3 percent per year in Eastern Europe and the former Soviet Union (EE/FSU), and 3.2 percent globally. In the developing countries, annual natural gas consumption is projected to almost triple over the forecast period. By comparison, nuclear electricity consumption in the developing countries is projected to grow at a rate of 4.7 percent per year, oil and coal at 3.2 percent per year, and renewable energy (primarily hydropower) at 3.0 percent per year. The largest increments in natural gas use are expected in developing Asia and North America, and the smallest increments are expected in Africa and the Middle East (Figure 33).

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 *IEO2002* reference case, the projections for natural gas consumption by electricity generators show more rapid growth than the projections for any other fuel. Natural gas consumption for electricity generation is projected to grow by 4.0 percent per year in the industrialized countries, compared with -0.1 percent for oil and 0.9 percent for coal, accounting for 56.3 percent of the projected increase in total energy used to generate electricity. World gas consumption for electricity generation more than doubles in the forecast, from 27.2 trillion cubic feet in 1999 to 58.9 trillion cubic feet in 2020, and consumption in the developing countries is projected to triple, from 5.9 trillion cubic feet in 1999 to 17.7 trillion cubic feet in 2020.

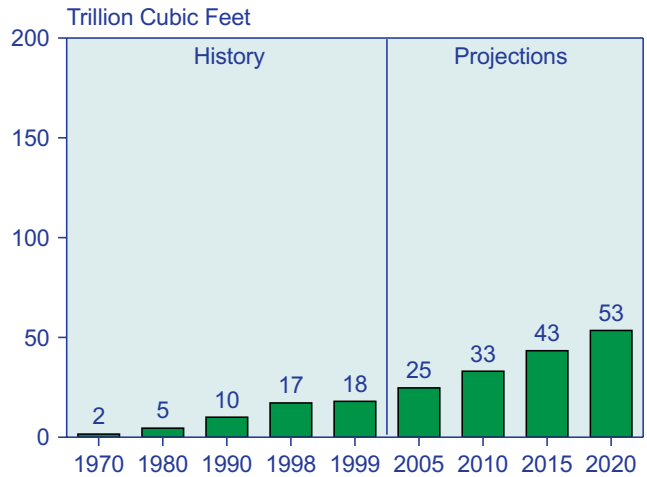
Although coal is expected to remain the predominant fuel used for power generation, natural gas is projected to capture 24 percent of the power generation market in the industrialized countries and 21 percent in the developing countries in 2020, up from 14 percent and 13 percent, respectively, in 1999. The natural gas market share

Figure 31. World Natural Gas Consumption, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

Figure 32. Natural Gas Consumption in the Developing World, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

of total world energy consumption for electricity generation in 2020 is projected to be 26 percent, compared with coal's 32 percent.

The use of natural gas is increasing for a variety of reasons, including price, environmental concerns, fuel diversification and/or energy security issues, market deregulation (for both gas and electricity), and overall economic growth. In many countries, governments hold equity in natural gas companies, and this can be used as a policy instrument. Examples include Kogas (Korea), Petronas (Malaysia), Pertamina (Indonesia), China National Petroleum Corporation, Gazprom (Russia), Pemex (Mexico), Oman LNG, Adgas (subsidiary of Abu Dhabi National Oil Company), National Iranian Oil Company, Sonatrach (Algeria), Nigerian National Petroleum Corporation, Egyptian General Petroleum Company, and Mossgas in South Africa. Most of these governments are fostering the expansion of their respective natural gas markets.

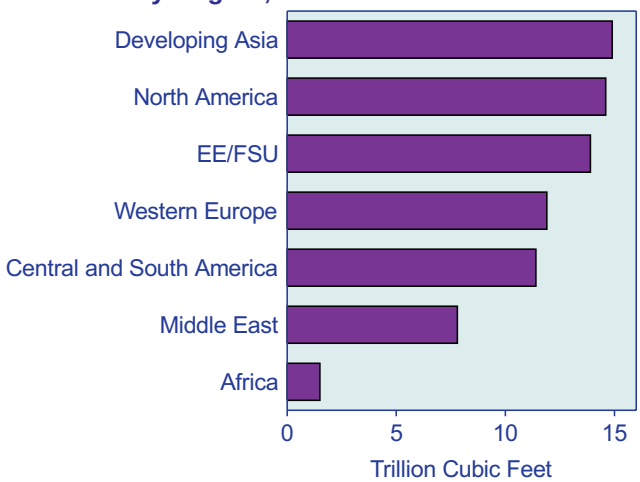
The amount of natural gas traded across international borders continues to grow, increasing from barely 20 percent of the world's consumption in 1999 to 22 percent in 2000 [***1***]. Pipeline exports grew by 8 percent and liquefied natural gas (LNG) trade grew by 10.3 percent between 1999 and 2000. Numerous 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 more economical, 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 and 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

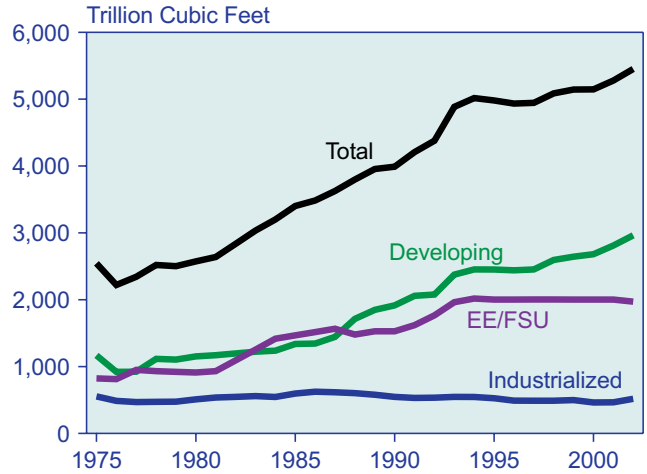
Since the mid-1970s, world natural gas reserves have in general increased each year (Figure 34). As of January 1, 2002, proved world natural gas reserves,[5] as reported by *Oil & Gas Journal*, were estimated at 5,451 trillion cubic feet, 173 trillion cubic feet more than the estimate for 2001. Most of the increase is attributed to developing countries, where gas reserves have increased by 152 trillion cubic feet since last year's survey. Natural gas reserves in the industrialized countries also increased

Figure 33. Increases in Natural Gas Consumption by Region, 1999-2020



Sources: **1999:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **2020:** EIA, World Energy Projection System (2002).

Figure 34. World Natural Gas Reserves by Region, 1975-2002



Sources: **1975-1993:** "Worldwide Oil and Gas at a Glance," *International Petroleum Encyclopedia* (Tulsa, OK: PennWell Publishing, various issues). **1994-2002:** *Oil & Gas Journal* (various issues).

[5]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 probable category. Natural gas reserves reported by the *Oil & Gas Journal* are compiled from voluntary survey responses and do not always reflect the most recent changes. Significant gas discoveries made during 2001 are not likely to be reflected in the reported reserves.

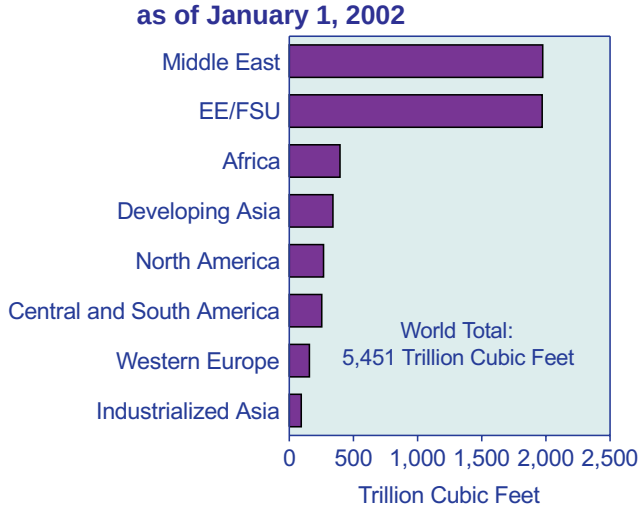
between 2001 and 2002, by 52 trillion cubic feet. EE/FSU reserves declined by 31 trillion cubic feet—mostly as a result of lowered estimates for Russia and for the East European countries Hungary and Romania, where reserves were halved over the past year.

The majority (about 72 percent) of the world's natural gas reserves are located in the Middle East and the FSU (Figure 35). Russia and Iran together account for almost one-half of the world's natural gas reserves (Table 14). 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 60.0 years [***2***]. Central and South America has a reserves-to-production ratio of 71.8 years, the FSU 79.6 years, and Africa 86.2 years. The Middle East's reserves-to-production ratio exceeds 100 years.

The largest expansion in natural gas reserves between 2001 and 2002 occurred in the Middle East, where 120 trillion cubic feet was added to the region's reserve base. Of that amount, 115 trillion cubic feet was attributed to revised estimates of Qatar's reserves by officials of Qatargas and Rasgas [***3***]. Developing Asia also saw an increase in reserves of 23 trillion cubic feet over the past year. Among the developing Asian countries, the greatest increase in proven reserves was in Indonesia, where reserves grew by 20 trillion cubic feet. Pakistan and Papua New Guinea, and to a lesser extent the Philippines and Thailand, also saw modest increases in gas reserves. Malaysia was the only developing Asian country with a notable decline in reserves, from 82 trillion cubic feet in 2001 to 75 trillion cubic feet in 2002.

Figure 35. World Natural Gas Reserves by Region as of January 1, 2002



Source: "Worldwide Look at Reserves and Production," *Oil & Gas Journal*, Vol. 99, No. 52 (December 24, 2001), pp. 126-127.

In the industrialized world, reserves have remained fairly stable for much of the past 20 years. In both North America and industrialized Asia, reserves increased from 2001 to 2002. In North America, an increment of 10 trillion cubic feet in U.S. natural gas reserves offset declines in Canada and Mexico. In industrialized Asia, Australia's reserves increased by 45 trillion cubic feet, more than doubling its reserve estimate from 2001.

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 5,196 trillion cubic feet (Figure 36), which is approximately double the worldwide cumulative consumption forecast in *IEO2002*. Reserves plus resources are four times the cumulative consumption forecast.

Of the new natural gas resources expected to be added over the next 25 years, reserve growth accounts for 3,660

Table 14. World Natural Gas Reserves by Country as of January 1, 2002

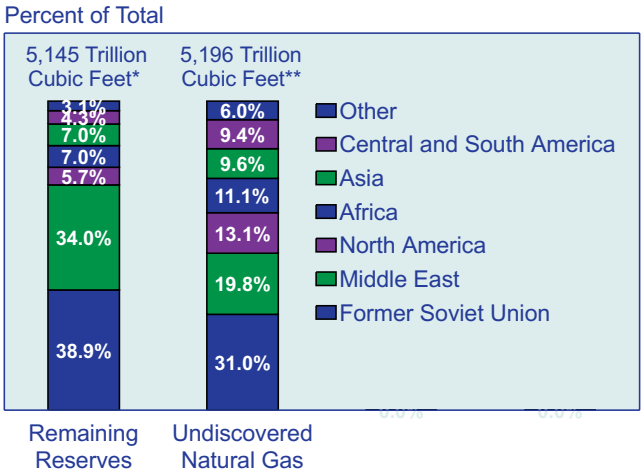
Country	Reserves (Trillion Cubic Feet)	Percent of World Total
World	**5,451**	**100.0**
Top 20 Countries	**4,863**	**89.2**
Russia	1,680	30.8
Iran	812	14.9
Qatar	509	9.3
Saudi Arabia	219	4.0
United Arab Emirates	212	3.9
United States	177	3.3
Algeria	160	2.9
Venezuela	148	2.7
Nigeria	124	2.3
Iraq	110	2.0
Turkmenistan	101	1.9
Indonesia	93	1.7
Australia	90	1.7
Malaysia	75	1.4
Uzbekistan	66	1.2
Kazakhstan	65	1.2
Netherlands	63	1.1
Canada	60	1.1
Kuwait	52	1.0
China	48	0.9
Rest of World	**588**	**10.8**

Source: "Worldwide Look at Reserves and Production," *Oil & Gas Journal*, Vol. 99, No. 52 (December 24, 2001), pp. 126-127.

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 an additional 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.

Figure 36. World Natural Gas Resources by Region, 2000



*As of January 1, 2000.
**Through 2025.
Source: U.S. Geological Survey, *World Petroleum Assessment 2000*, web site http://greenwood.cr.usgs.gov/energy/WorldEnergy/DDS-60.

Regional Activity

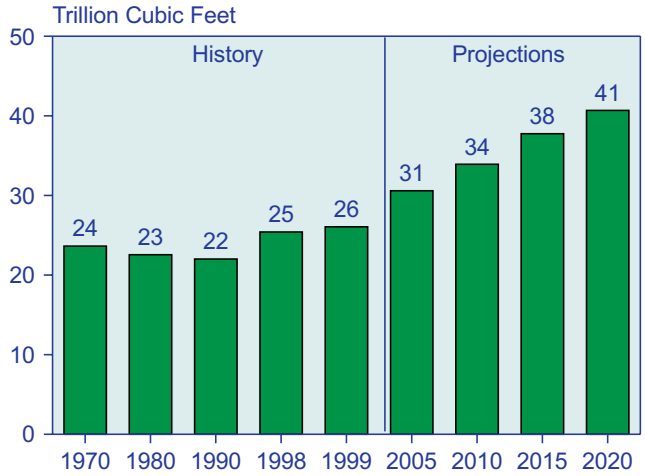
North America

Natural gas consumption in the *IEO2002* forecast for North America is projected to grow at a rate of 2.1 percent per year between 1999 and 2020 (Figure 37). Demand for gas is projected to increase in all three countries of the region (United States, Canada, and Mexico), but the most rapid growth rates are projected for Mexico, where the present immature gas infrastructure is expected to expand over the forecast period (Figure 38). The North American region is rapidly moving toward becoming an integrated gas market, and a substantial increase in the movement of natural gas between the United States, Canada, and Mexico is expected in the future.

United States and Canada

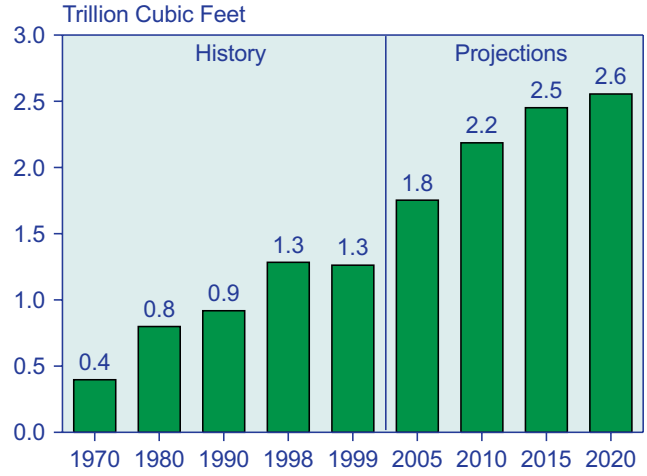
The United States currently is the dominant consumer of natural gas in North America, and it is expected to remain in that position throughout the projection period. Total U.S. natural gas consumption is projected to increase from 22 trillion cubic feet in 1999 to 34 trillion cubic feet in 2020 (compared with Canada's projected 4 trillion cubic feet in 2020 and Mexico's 3 trillion cubic feet). Much of the increment in U.S. gas use is expected in the electricity sector, where electricity generators (excluding cogenerators) are projected to account for 55

Figure 37. Natural Gas Consumption in North America, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

Figure 38. Natural Gas Consumption in Mexico, 1970-2020



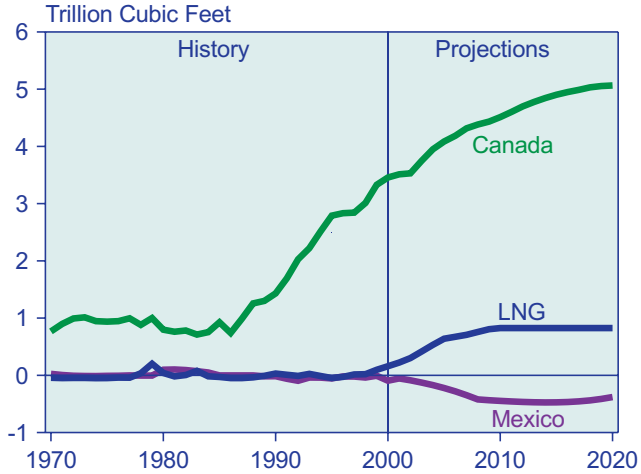
Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

percent of total U.S. natural gas consumption by 2020, according to the Energy Information Administration's *Annual Energy Outlook 2002* (*AEO2002*) [***4***]. Electricity generation is expected to surpass the industrial sector as the largest consumer of natural gas in the United States, with lower capital costs, higher fuel efficiency, shorter construction lead times, and lower emissions favoring natural-gas-fired generation over coal-fired generation.

Natural gas accounts for 25 percent of Canada's total energy consumption, and its share is not expected to change substantially over the projection period. Because the country already relies on its ample supply of cheap hydroelectric power to provide more than one-half of its electricity supply, natural-gas-fired generating capacity is not expected to expand as dramatically as in the United States. As a result, much of Canada's natural gas production is expected to be exported to the United States, where increasing demand will be greatest. Record high prices for natural gas in the United States in 2000 underscored the potential benefits to Canadian gas exporters. Canada's natural gas exports provided significant increases in revenues to producers, accounting for close to two-thirds of the country's 2000 trade surplus. It is estimated that Canadian gas revenues reached $13.8 billion, compared with estimated 1999 revenues of $7.3 billion [***5***].

As the U.S. demand for natural gas increases, the country will come to rely more heavily on imports, particularly from Canada (Figure 39). Over the past several years, the United States has experienced a widening gap between production and consumption, and in 2000 it consumed 18.0 percent more than it produced. The difference was made up with pipeline imports from Canada and Mexico and LNG imports from numerous sources, including Algeria, the United Arab Emirates, Australia, Qatar, Trinidad and Tobago, Malaysia, Nigeria, Oman, and Indonesia. Canada accounted for 93.8 percent of U.S. natural gas imports in 2000, LNG 5.9 percent, and Mexico 0.3 percent.

Figure 39. Net U.S. Imports of Natural Gas, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001).

Imports into the United States from Canada in 2000 were 5.2 percent higher than in 1999, and during the first 9 months of 2001 they were 10 percent higher than over the same period in 2000 (2.9 trillion cubic feet vs. 2.6 trillion cubic feet) [***6***]. Over the past several years, cross-border pipeline capacity has increased considerably between the two countries. Most recently, the Alliance Pipeline was completed in December 2000, allowing 1,325 million cubic feet per day of natural gas from western Canada to be moved through North Dakota and into Chicago.

Although recent pipeline additions have provided significant increases in cross-border capacity between western Canada and the United States, there are pipeline bottlenecks within Canada that prevent some new supplies from reaching U.S. markets. There are several projects underway to alleviate this problem. Canadian Natural Resources (CNR), for example, has received approval to construct a pipeline from Ladyfern (where a discovery in 2000 is estimated to be one of the most prolific gas discoveries in western Canada in the past 15 years) in northeastern British Columbia to Northwestern Alberta, where it can then link up with TransCanada Pipeline's transcontinental network to move gas to southern Canada and the United States. The new pipeline is scheduled for completion in March 2002. It will have an initial capacity of 680 million cubic feet per day but could eventually be expanded to 1.35 billion cubic feet per day [***7***].

Another project aimed at increasing Canada's ability to export natural gas to U.S. markets is being implemented in eastern Canada. Maritimes and Northeast Pipeline plans to increase pipeline capacity to 1 billion cubic feet per day to bring in new reserves from offshore Atlantic Canada. According to Maritimes and Northeast president Phillip Knoll, the existing system can be economically expanded through compression and looping to allow producers competitive rates for getting their supplies to New England markets for new gas-fired generators [***8***].

U.S. imports of LNG are expected to quadruple over the next two decades, increasing the LNG share of gas imports to 14.7 percent in 2020. The development of an LNG market in the United States has been constrained by limitations on the amount it can receive and regasify. There are currently four LNG receiving facilities in the United States. Two have been operating for several

years, one in Everett, Massachusetts, and one in Lake Charles, Louisiana. In September 2001, a facility reopened at Elba Island, Georgia, after several years of inactivity. The fourth facility is scheduled to reopen at Cove Point, Maryland, by mid-2002.

Algeria was the only source of LNG supply for the United States until May 1999, when supplies began arriving from Trinidad and Tobago. Trinidad and Tobago has now replaced Algeria as the primary source of U.S. LNG supply. Trinidad and Tobago and Algeria currently have the only long-term contract sales for LNG, but spot cargos have been imported from Qatar, Nigeria, Australia, Oman, Indonesia, and the United Arab Emirates, and spot market sales in the U.S. market continue to grow [***9***]. In the third quarter of 2001, short-term LNG imports totaled 51.3 billion cubic feet, compared with 44.7 billion cubic feet in the third quarter 2000.

As a result of the renewed interest in LNG, numerous additional facilities are being considered, including sites in the Gulf of Mexico, North Carolina, and Florida; however, siting an LNG receiving terminal in the United States can be a formidable task. Aside from the geographical requirements, the NIMBY (Not In My Back Yard) factor can be close to insurmountable and is likely to be the most important factor in whether a facility is built at a particular location. To avoid this problem, there have been proposals to site the facilities outside US borders, notably, in Baja California (Mexico) and in the Bahamas. Local opposition makes the prospect of new facilities to serve U.S. markets uncertain for the near future.

The opposition to new LNG receiving facilities does not preclude expansion at existing facilities, however. El Paso subsidiary Southern LNG has plans to expand its Elba Island facility by 80 percent, adding 360 million cubic feet per day of sendout capacity to its current 440 million cubic feet per day. The added capacity is expected to be in place by June 1, 2005 [***10***]. Talk of new facilities continues in spite of a significant drop in natural gas prices over the past year, with many developers stating that even with the current U.S. prices of under $3.00 per thousand cubic feet, they expect LNG to be economical in the future and are proceeding with their plans. The *AEO2002* forecast projects expansion of existing facilities and increases in gross LNG imports averaging 7.1 percent per year, from 220 billion cubic feet in 2000 to 890 billion cubic feet in 2020.

Mexico

In Mexico, natural gas consumption has been growing, but production has been falling. Mexico's consumption of natural gas is projected to increase by 3.4 percent per year between 1999 and 2020, with much of the increase in the industrial sector and for new electricity generation. As a result of the widening gap between production and consumption, Mexico has had to increase imports, and its import capacity is also being expanded with an eye to the future. In October 2000, the bidirectional Coral Energy pipeline between Mexico and the border near McAllen, Texas, became operational (300 million cubic feet per day). Exports from the United States to Mexico increased by 72 percent between 1999 and 2000 and by 24 percent between the first 9 months of 2000 and the first 9 months of 2001 (98 billion cubic feet vs. 79 billion cubic feet) [***11***]. In addition, Tidelands Oil and Gas, based in Texas, has filed for approval to build three 6-mile pipelines from Eagle Pass in Texas to Piedras Negras in Mexico, which would supplement the current capacity at nine existing border crossings [***12***].

El Paso Natural Gas has filed to increase its capacity at the Mexican border from 208 million cubic feet per day to 308 million cubic feet per day [***13***]. According to El Paso, the increase is to meet Mexico's need for 60 million cubic per day of natural gas initially to fuel the new Chihuahua II power plant in El Encino and an additional 40 million cubic feet per day for a new turbine generator to be installed in February 2002. El Paso plans to add the capacity by increasing compression along the existing Samalayuca Lateral. Another major incentive for increased capacity between the United States and Mexico, according to El Paso, is the rapid development of northern Mexico's pipeline infrastructure [***14***].

In addition to pipeline imports, LNG is expected to meet some of Mexico's growing demand, and several LNG receiving facilities have been proposed to serve markets in northwestern Mexico and southern California. Sempra Energy and CMS Energy have proposed a joint venture for a terminal north of Ensenada in Mexico's Baja California with a sendout capacity of 1 billion cubic feet per day; Phillips Petroleum and El Paso Corporation have proposed a 630 million cubic feet per day facility; El Paso is also considering a terminal to be located offshore California; and Chevron is evaluating both offshore California and Baja California for a 750 million cubic feet per day facility [***15***]. Shell Oil, in partnership with El Paso, is planning a 0.5 to 1.0 billion cubic feet per day receiving facility in Mexico's east coast Tamaulipas state at Altamira that would receive gas from Africa, the Carribean, and South America. Turning towards South America, Mexico has had preliminary talks outlining an economic agreement with Bolivia that would allow the Pacific LNG consortium (Respol-YPF, British Gas, and British Petroleum), to use Mexico's pipelines and plants to process LNG from Bolivia to be exported to the United States for use in southern California [***16***]. The arrangement would also provide Mexico with Bolivian gas for its own use.

Mexico is also struggling to restructure its natural gas industry in order to develop its vast natural gas resources. Two factors that hinder more rapid expansion of the gas market in Mexico are the complete control of the exploration and production sector of the market by Petroleos Mexicanos (Pemex), the state oil and gas company, and the lack of infrastructure to move gas from the main producing areas in the south to the major consuming regions in the north. While the distribution segment of the industry has been open to private investment since 1995 and has seen significant growth in recent years, exploration and production continue to be controlled by Pemex.

The Mexican government feels it is imperative that progress be made in opening the natural gas production sector, because the government does not have the financial resources to fully develop the country's reserves. To this end, Pemex is working to develop a multiple-service contract that can be used to get foreign investors to help develop Mexico's natural gas. According to Dominguez Vargas, first vice-president of technology and professional development for Pemex, the initial emphasis would be on getting contracts in place for development efforts in the Burgos basin in northeastern Mexico, where the largest production increase could be achieved [***17***].

The situation is a difficult one for Mexican President Vicente Fox, who took office on December 1, 2000. Most of Mexico's current natural gas production is associated with light crude oil production, and the declining ratio of light crude to total crude production yields a corresponding decline in associated gas production [***18***]. According to Energy Minister Ernesto Martens, Mexico will need to increase its gas production from the current 5 billion cubic feet per day to 12 billion cubic feet per day by 2006 [***19***]. The Fox administration favors restructuring Mexico's energy markets, but it will be difficult to implement any sweeping reform, because the party lacks a majority in both of the Mexican government's legislative bodies. At a minimum, Fox has indicated that he intends to open up exploration and development of nonassociated gas to private investment.

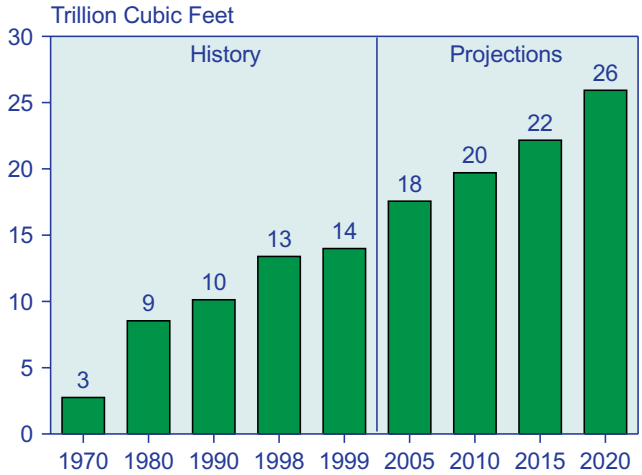
Western Europe

Natural gas is the fastest growing fuel source in Western Europe, despite the region's limited natural gas resources. The region accounts for less than 5 percent of the world's natural gas reserves but in 1999 consumed 17 percent of the world total. Over the next two decades, natural gas consumption in Western Europe is projected to grow at an average annual rate of 3.0 percent in the *IEO2002* reference case forecast, compared with a rate of 1.0 percent for total primary energy consumption (Figure 40). In addition to a preference for natural gas over coal for environmental reasons, Europe's natural gas use is growing due to readily available supplies to supplement domestic production coming by pipeline from the FSU and Algeria, and by tanker in the form of LNG from a number of sources. Recent demand increases reflect rising gas use for power generation and for the industrial sector. Consumption of natural gas for electricity generation is projected to more than double over the projection period.

The European Union (EU) has played an important role in the development of Western Europe's natural gas markets, passing key legislation over the past several years to liberalize both the electricity and natural gas markets of its member countries. The EU Directive on Electricity was passed in January 1997, opening up electricity markets in member nations to competition within 2 years, and its Natural Gas Directive was passed in June 1998 requiring the opening of gas markets.

The objective of the Natural Gas Directive is to ensure the free movement of natural gas and improve security of supply and industrial competitiveness. It established common rules for the EU's internal natural gas market regarding the storage, transmission, supply, and distribution of natural gas. The rules addressed market access, criteria and procedures for systems operations, and the granting of licences for natural gas supply, transmission, storage, and distribution. The Directive set a deadline of August 10, 2000, for members (with the exception of emerging markets in Portugal and Greece) to have arrangements in place for third-party access to gas infrastructure. By that date all gas-fired power generators and customers using more than 883 million cubic feet of natural gas per year were to be eligible to choose a

Figure 40. Natural Gas Consumption in Western Europe, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

gas supplier. Customers using at least 530 million cubic feet per year are to be eligible by 2003, and those using at least 177 million cubic feet per year are to be eligible by 2008.

In May 1999 a report by the European Commission (a branch of the EU) was released, calling for the acceleration of the gas market liberalization from 2008 to January 2005 at the latest [***20***, ***21***]. Subsequently, on March 13, 2001, the Commission outlined the current state of progress, recommending the following measures to achieve the accelerated gas market objective:

- Adoption of appropriate rules with respect to the pricing of cross-border trade
- Adoption of rules for allocation and management of interconnection capacity
- Where economically justified, increasing existing physical interconnection capacity.

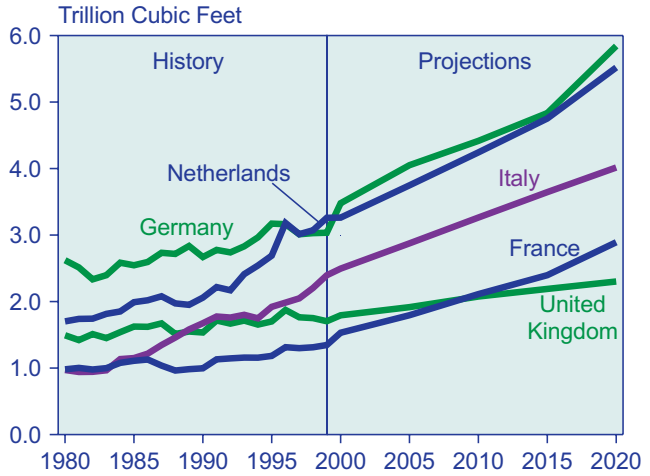
The largest consumers in Western Europe by far are the United Kingdom, Germany, Italy, the Netherlands, and France, and consumption in these countries is expected to grow steadily over the forecast period (Figure 41). More than one-half of the region's resources are concentrated in the United Kingdom, the Netherlands, and Norway, which are the region's primary producers. Almost all Western European gas production is consumed internally, with the exception of small quantities exported by France, Germany, and Norway to Eastern European markets.

Although the projected incremental increases in consumption are far less than those in the largest consuming countries, some of the most rapid growth rates in natural gas consumption in Western Europe are occurring in countries where natural gas markets are just beginning to flourish—including Portugal, Greece, Ireland, and Spain (Figure 42). Portugal and Greece are two of the smallest economies represented in the EU and are considered by the EU to be emerging gas markets, a status that gives them flexibility in meeting the deadlines of the Natural Gas Directive for opening their gas markets. Both countries consumed less than 10 billion cubic feet per year before 1998, when consumption in Portugal jumped to 28 billion cubic feet and in Greece to 30 billion cubic feet. Consumption in both countries rose dramatically again in 1999, to 80 and 53 billion cubic feet, and the growth is continuing. Natural gas markets in Ireland and Spain have been developing for a longer period, and recent consumption increases, while not as impressive, are nonetheless significant.

Portugal

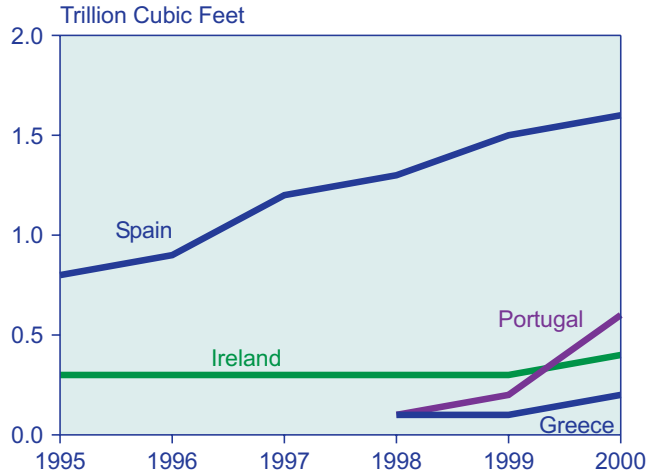
In Portugal, the natural gas market is less than 5 years old. There was no measurable consumption until 1997, when the Maghreb-Europe pipeline connected the Iberian peninsula to Algerian gas sources (via Morocco). Since then, gas use has risen steadily. Although virtually all of Portugal's natural gas still comes by pipeline from Algeria, it also began importing LNG in 1998 and in 1999 entered into a contract to purchase LNG from Nigeria for 20 years beginning in 2002. The LNG will be regasified initially in Spain and piped into Portugal until a terminal under construction at Sines, Portugal, scheduled to become operational in 2003, is completed. The Sines terminal will have a capacity of 580 billion cubic feet per year and will be operated by Transgas.

Figure 41. Natural Gas Consumption in Five Countries of Western Europe, 1980-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

Figure 42. Natural Gas Consumption in Four Countries of Western Europe, 1995-2000



Source: Energy Information Administration, Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001).

Almost all of the natural gas consumption in Portugal is to fuel electricity generation. A member of the EU, Portugal has received EU assistance in investment in its gas infrastructure. Approximately $417 million (485 million euros) was spent on improving Portugal's infrastructure between 1994 and 1999, when the EU decided to cut back on spending. Nevertheless, there are still plans to expand the network from 3,761 miles in 1999 to 5,943 miles in 2010 [***22***]. Under the EU Gas Directive, as an emerging natural gas market Portugal is not required to open its domestic gas market to full competition until 2008. It was, however, required to open at least 33 percent of its market to competition by 2001—a target that still has not been met. As a result, the EU has begun infringement procedures.

Greece

In Greece, the government historically has maintained a prominent role in the energy industry, and the natural gas market remains under the control of the state-owned Greek Public Gas Company (DEPA). DEPA was established in 1988 to promote natural gas use in order to diversify Greece's energy sources, but the market actually declined until 1997 when the government loosened its control on the industry and allowed foreign participation. Since that time, rapid expansion has been occurring.

A member of the EU, Greece has taken full advantage of all the EU waivers its emerging market status allows in order to delay EU-mandated energy sector privatization, and it is only recently that privatization has made any inroads. Under agreements signed in July 2001, a new distribution company, EDA Attikis, 51 percent of which is owned by DEPA and the remainder by Cinergy of the United States and Royal Dutch/Shell, will supply Athens and its surrounding areas with natural gas, covering 30 percent of Greece's population. Although Athens was the first Greek city to have a gas distribution network, at present only about 8,000 customers are connected to the network in a city of more than 3.1 million [***23***]. EDA Attikis plans to expand the network to reach 55 percent of the region's population and expects demand to reach about 35 billion cubic feet by 2020. In 2000, the Italian utility company, Italgas (a subsidiary of ENI), won 30-year concessions to build and operate two city gas distribution networks, in Thessaloniki and Thessaly; and it will have a minority stake in the network ownership and management of each. DEPA has the exclusive contract to supply the three distribution networks for 15 years [***24***].

Greece intends to diversify its import sources, and in July 2000 it agreed to work with Turkey to develop connections between their natural gas networks. The two countries have agreed to work with the EU-sponsored Interstate Oil Gas Transport to Europe (INOGATE) project, which provides technical assistance to modernize oil and gas transport in central Europe and Asia in order to work toward European pipeline linkages to Caucasus and Asian oil and gas.

In March 2001, Greece signed an agreement with Armenia and Iran to strengthen economic and energy cooperation. Discussions included the possibility of an EU-subsidized natural gas pipeline from Iran through either Armenia and Ukraine or Turkey and Greece to other European customers. LNG is also a source of imports for Greece. The country began importing LNG from Algeria in late 1999 into its LNG terminal at Revithoussa, near Athens. The terminal is small, with a receiving capacity of 23 billion cubic feet per year. It is possible that the terminal could be expanded, or that an additional terminal could be built: however, an undersea natural gas pipeline from Italy to Greece is currently in the feasibility study phase [***25***], and if that project is approved it could reduce the impetus to expand LNG markets in Greece.

Ireland

In Ireland, switching to natural gas is seen as a way to reduce carbon dioxide emissions from electricity generation. According to the Ireland Department of Public Enterprise, close to half of Ireland's natural gas consumption is currently for electricity generation, and its share is expected to continue to increase [***26***]. There is also a strong move to continue the expansion of the residential and small commercial/industrial markets that have been growing as the distribution infrastructure expands. Phoenix Natural Gas, in particular, is currently focusing on this market.

At present, Ireland's only indigenous source of natural gas is the Kinsale Head Gas Field, which has been producing since 1978. The field is now in decline and is expected to be depleted by 2004. Dependence on imports is thus climbing as gas use accelerates. In 2000, one-half of Ireland's consumption of 134 billion cubic feet was imported from the United Kingdom. Kinsale production is likely to be supplemented in 2002 with supplies from the Corrib Gas Field, a recently discovered field off Ireland's northwest coast.

Natural gas imports to Ireland were first made possible by the completion of the 180-mile Interconnector from Scotland, with a capacity of 194 billion cubic feet per year [***27***]. Expansion of the country's pipeline transmission infrastructure is currently underway. The Celtic Energy consortium is planning to construct a pipeline linking North Dublin to Wales and England, scheduled for completion by the end of 2002, and the Premier Transco group is assessing the possibility of a pipeline linking Belfast and Dublin. Bord Gais Eireann has submitted an application to construct three natural gas

transmission pipelines: (1) to the west, from Dublin to Limerick to Galway Ringmain; (2) from Mayo to Galway; and (3) a second Scotland to Ireland Interconnector.

Spain

Strong growth in natural gas use is occurring in Spain as the country phases out its older nuclear and coal power plants in favor of gas. Estimates are that Spain could easily double its gas consumption by 2010 [***28***]. Spain is almost entirely dependent on imports to satisfy its gas demand, and that situation is not expected to change in the foreseeable future. The country's domestic resources are limited: its one major gas field ceased production in 1995, and there have been no new discoveries since then. In 2000, Spain imported half of the gas it consumed by pipeline from Norway and Algeria (primarily Algeria).

The remaining half of Spain's natural gas comes in the form of LNG. It is imported from a number of countries, including (in order of magnitude) Algeria, Nigeria, Libya, Trinidad and Tobago, Qatar, United Arab Emirates, Malaysia, and Oman. In fact, Spain is one of Europe's largest importers of LNG, second only to France. Spain currently has three LNG receiving terminals, all operated by Enagas, located in Barcelona, Huelva, and Cartagena. The three terminals, with a combined capacity of 500 billion cubic feet per year, became operational in 1969, 1988, and 1999. There is also considerable growth in LNG receiving capacity on the horizon, with two new terminals currently under construction and a third in the planning stage. The first of those under construction is scheduled to come online in 2003 in the port of Bilboa in the northern Basque region and be operated by Bahia de Bizkaia Gas. The second is expected to come online in 2005 in Valencia and be operated by Union Fenosa. The proposed terminal, to be located in Murgardos, will be operated by Union Fenosa, Endesa, and Sonartrach, in addition to local companies [***29***].

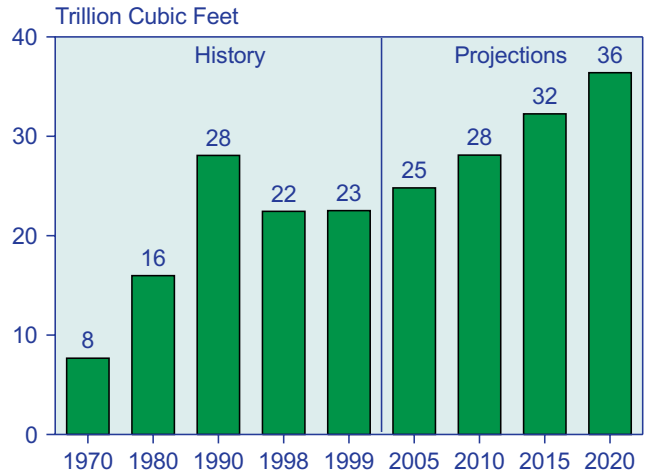
Eastern Europe and the Former Soviet Union

With 2,003 trillion cubic feet of proven natural gas reserves, the FSU accounts for 38 percent of the world total. Russia lays claim to 85 percent of those reserves, making it the largest potential source of natural gas in the world. Reserves in Iran, which is second to Russia, amount to less than one-half of Russia's total. Other gas producing countries in the FSU include Turkmenistan, Uzbekistan, Ukraine, and Kazakhstan. Of the four, Turkmenistan contains just over 100 trillion cubic feet of reserves, accounting for almost 2 percent of the world's total reserves, and the others each account for around 1 percent of the world's total.

Unstable political and economic conditions in the early to mid-1990s led to significant declines in EE/FSU natural gas markets. Between 1990 and 1998, consumption declined by more than 20 percent. Although the declining trend has been reversed, the region still falls far short of both the production and consumption levels realized in 1990. Gas markets in the EE/FSU continue to face a number of complex issues, including curtailments, nonpayment, declining Russian production, transit disputes, and economic and political conditions that have not been conducive to foreign investment. Restructuring of gas markets is occurring, however, and the prospects for natural gas market growth in the EE/FSU look promising. The *IEO2002* forecast is for increased growth, with consumption increasing at an average annual rate of 2.3 percent over the forecast period, from 23 trillion cubic feet in 1999 to 36 trillion cubic feet in 2020 (Figure 43). Growth in Eastern Europe is expected to far outpace growth in the FSU, with Eastern European consumption projected to grow at an average annual rate of 4.7 percent, compared with the FSU's 1.9 percent. This may be explained by the fact that most East European countries 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 positive economic growth.

Natural gas production in Russia declined by 1.1 percent in 2000, and Russia fell behind the United States to become the world's second rather than top natural gas producer for the first time in a decade. Russia consumed 69 percent of its own production, exporting the balance. Russia is the world's largest exporter of natural gas (Figure 44), supplying Europe with about 30 percent of its gas supplies. Russia's biggest European export markets are Germany, Italy, and France, each relying on Russia for more than one-third of its natural gas. Most

Figure 43. Natural Gas Consumption in the EE/FSU Region, 1970-2020



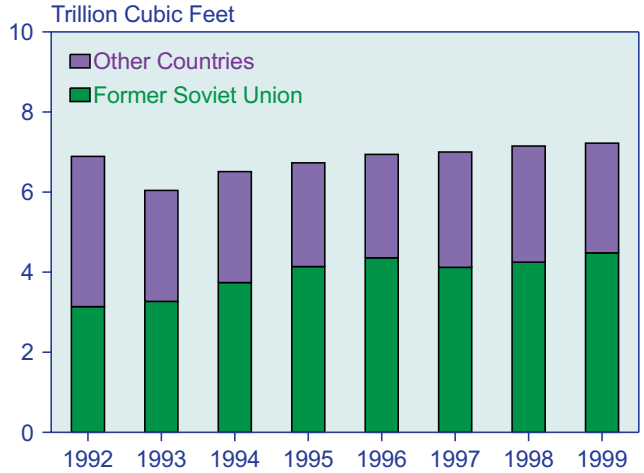
Source: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

EE/FSU countries continue to depend almost solely on Russia for their natural gas supplies. Russia has also begun to supply many of its customers, including Austria, Finland, Greece, Hungary, and Turkey, with well over half the natural gas they consume.

Russia has an extensive network of domestic pipelines as well as international pipelines linking it to export markets. Three pipelines, the Brotherhood (*Bratsvo*), Progress, and Union (*Soyuz*), deliver gas to Europe via Ukraine. A fourth pipeline, the Yamal, transits Belarus to reach European markets. A fifth, the Northern Lights, transits both Belarus and Ukraine en route to Europe. Gas markets in Finland are served by the Volga/Urals-Vyborg pipeline. A new pipeline slated to serve markets in Turkey via the Black Sea, the Blue Stream Pipeline, is currently under construction. Work began in February 2000, and Gazprom has completed the aboveground section of the pipeline from Russian territory to the Black Sea coast at Tuapse. Turkey has completed its segment of the line, from Ankara to the Black Sea coast at Samsun. The final segment will run beneath the Black Sea, connecting the Russian and Turkish sections of the project. Laying of the underwater segment began in August 2001, with completion scheduled for 2002 [**30**].

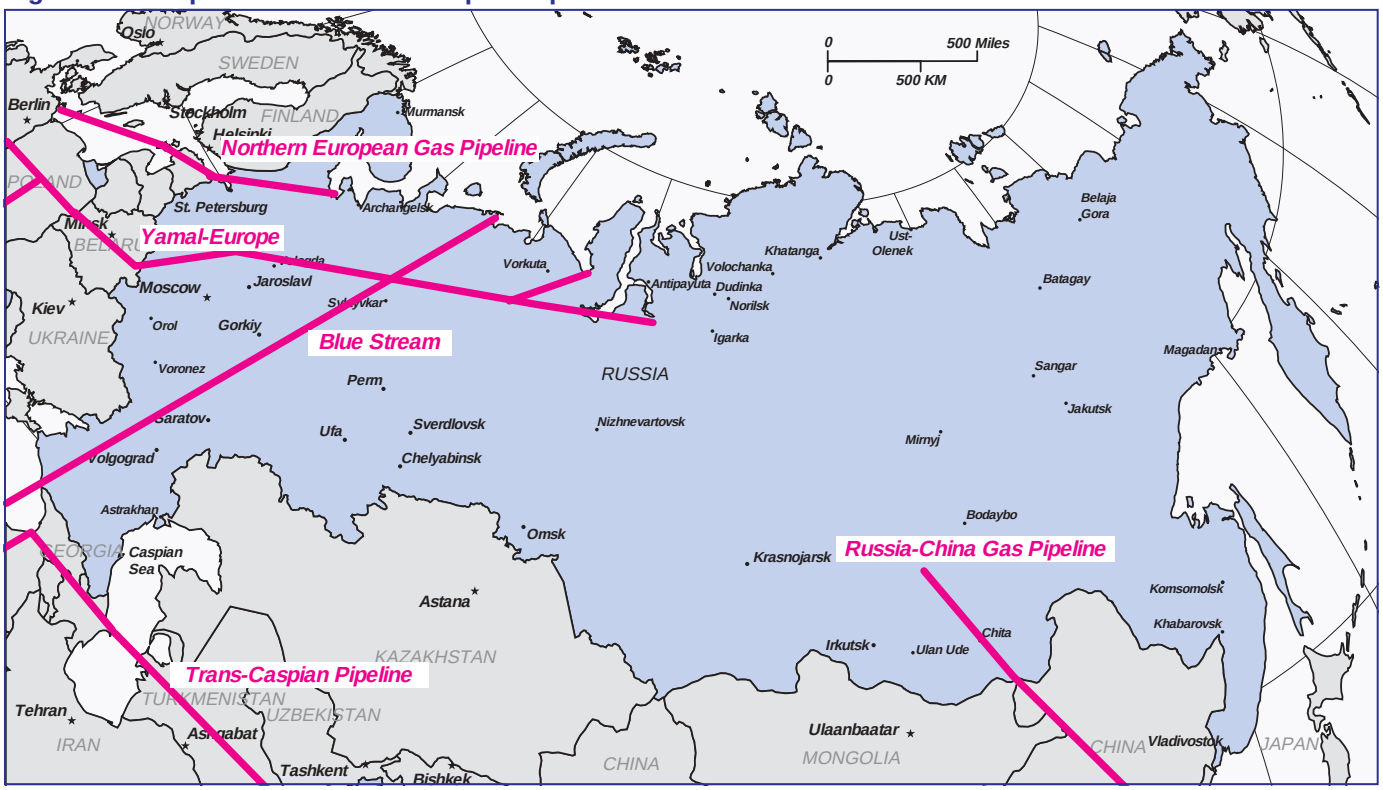
Russia hopes to both further expand its export capacity (Figure 45) and at the same time diversify its export markets so that it can ship less gas to debtor nations, such as Ukraine, and be less dependent on Ukraine as an export route. Ukraine currently serves as a transit route for more than 90 percent of Russia's exports to Europe. Problems between Russia and Ukraine continue, with Ukraine failing to keep current in its payments for gas imported from Russia, and Russia accusing Ukraine of siphoning gas it is not entitled to during transit, thus threatening Russia's European customers with natural gas shortages.

Figure 44. Russia's Net Natural Gas Exports, 1992-1999



Source: PlanEcon, *Energy Report*, Vol. 10, No. 1 (Washington, DC, May 2000), p. 38.

Figure 45. Proposed Natural Gas Export Pipelines from Russia



Source: P. Trafalgar, "Boom for Russia's Gas-Export Pipelines," *The Russia Journal* (November 23-29, 2001), p. 6

Russia plans to build the Yamal-Europe II pipeline, which would allow it to bypass Ukraine and, instead, transit Belarus, Poland, and Slovakia. A feasibility study is underway. One glitch is Poland's hesitancy to make a move that might damage the interests of Ukraine, because Ukraine is one of Poland's strategic allies. While Russia hopes to diversify its customer base, its customers have in turn attempted to reduce their dependence on Russia as a primary supplier, especially given the economic instability in Russia in the past. In order to diversify, Russia is exploring the possibility of exporting gas from eastern Siberia and/or Irkutsk to Asian markets, notably China, and several pipeline options are being considered. Gazprom has also undertaken a feasibility study on a pipeline, North TransGas, that would carry Russian gas across the Baltic Sea to serve Scandinavia and Germany. Firms developing the Sakhalin I field have proposed a pipeline to deliver Sakhalin gas to northern Japan and later Tokyo, and a feasibility study is being conducted [***31***].

Although Russian production declined in 2000, the FSU as a whole increased production by 2.7 percent, with production in Turkmenistan more than doubling and production in Kazakstan growing by 15.6 percent. Much of the increased production in Turkmenistan was exported, primarily to other EE/FSU countries but also to Iran. At present, Turkmenistan is Iran's only source of imports. Turkmenistan is the only former Soviet Republic except Russia that is exporting substantial volumes of natural gas. The country produces about 70 percent more gas than it currently consumes. Approximately 85 percent of the excess production is exported to Iran for use in Iran's non-producing northern areas, with the remaining 15 percent going to other EE/FSU countries. This is almost the reverse of the situation in 1999, when 30 percent of Turkmenistan's exports went to Iran and 70 percent to other EE/FSU countries.

Central and South America

Natural gas markets in Central and South America are relatively small, but they are growing rapidly, with considerable upstream and downstream development. *IEO2002* projects that gas consumption in Central and South America will grow to 14.6 trillion cubic feet by 2020, at an average annual growth rate of 7.4 percent (Figure 46).

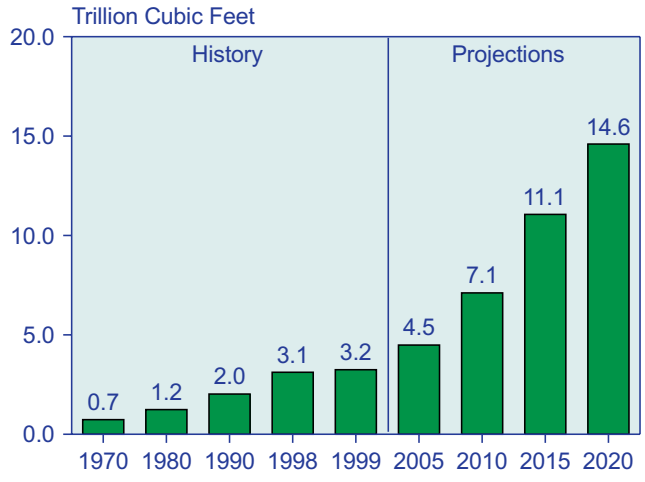
Because much of Central and South America has not yet been explored for gas, there is strong potential for new discoveries. Recent exploration activity has yielded promising discoveries, and the region's reserves have increased from 244 trillion cubic feet in 1999 to 253 trillion cubic feet in 2001. The highest concentrations of reserves are in Argentina and Bolivia in the Southern Cone Common Market, also referred to as Mercosur, and Venezuela and Trinidad and Tobago in the north.

Brazil

Consumption in Brazil has increased steadily over the past decade and is expected to grow at an average annual rate of 13.3 percent over the forecast period. Brazil is making an effort to diversify fuel use in its electricity generation sector, which is almost entirely dependent on hydropower. The country is currently experiencing an electricity shortage brought on by several years of below average rainfall that has left reservoirs less than 30 percent full and, in 2001, led the government to mandate that industrial and residential consumers reduce their electricity consumption by 20 percent. The energy crisis has added more urgency to plans for constructing substantial natural-gas-fired electricity generators. The Brazilian government is pressing to get 15 gas-fired power plants with a combined capacity of 6,423 megawatts operational by 2003 and has set a long-term goal of completing 55 new gas-fired generators before 2007 with a combined capacity of 23,000 megawatts [***32***] (see box on page 118). In an effort to promote natural gas use, plans are underway to privatize parts of the country's gas sector. Natural gas exploration and production historically have been controlled by the state company, Petrobrás, with distribution handled at the state level [***33***].

There are several pipeline projects available to serve the Brazilian markets, and several more are planned (Figure 47). One pipeline in operation connects Paraná, Argentina, to Uruguaiana, Brazil. It has been providing gas to a power plant in Uruguaiana since July 2000. An extension of the pipeline to Porto Alegre, Brazil, is currently under construction, with a targeted completion date of 2002.

Figure 46. Natural Gas Consumption in Central and South America, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

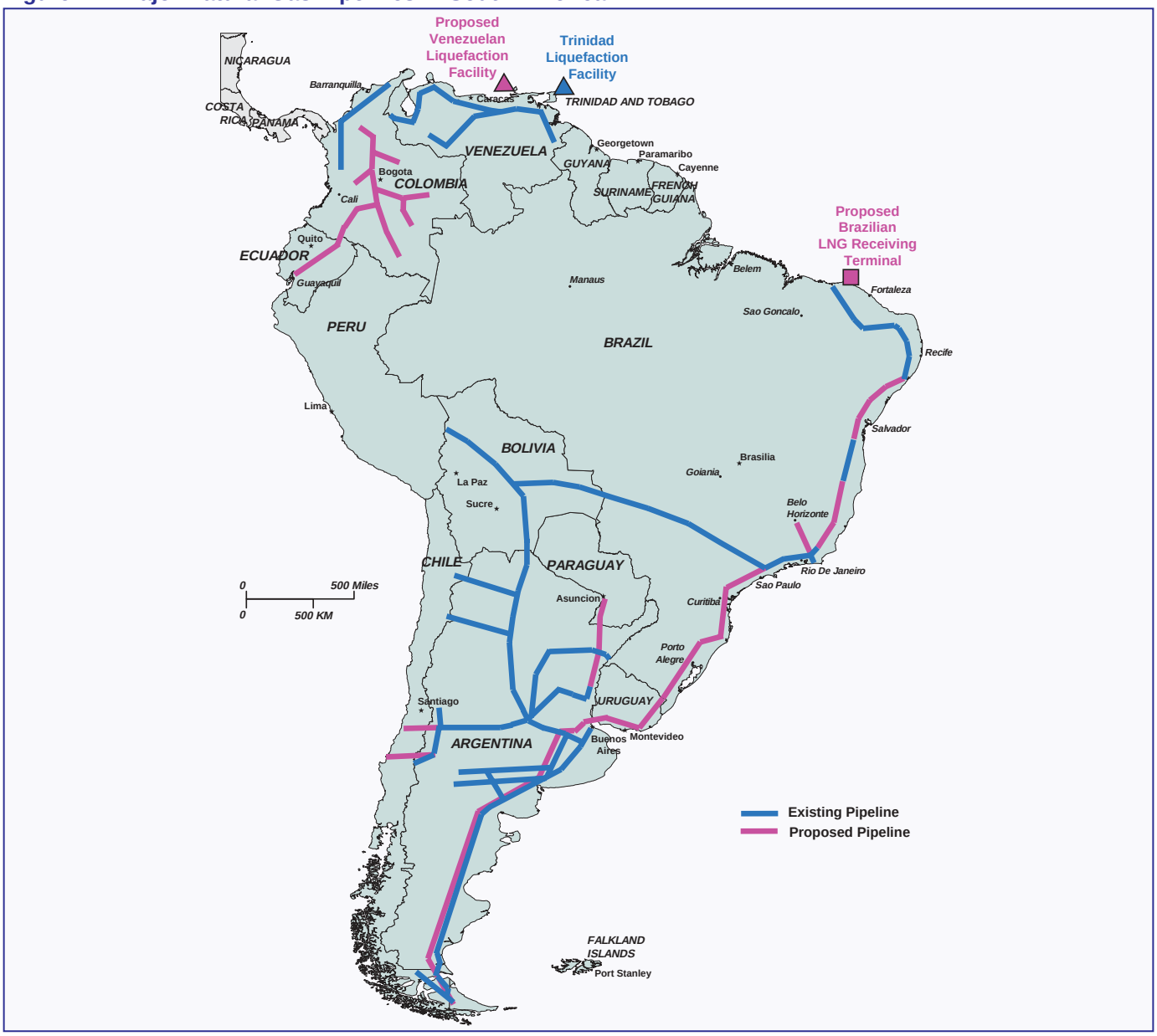
Additional Argentina-Brazil pipelines are in various stages of the planning process, although recent natural gas discoveries in Bolivia and potential Brazilian discoveries could prevent development of these pipeline projects. The potential Argentina-Brazil pipelines include the Cruz del Sur, Trans-Iguacu, and Mercosur pipelines. The Cruz del Sur would extend to Brazil an Argentine-Uruguayan pipeline that currently is under construction (construction began in March 2001, with the first deliveries slated for early 2002). The Trans-Iguacu pipeline would cross from northern Argentina's Noroeste basin into southern Brazil. The Mercosur pipeline would tap northwestern Argentina's Neuquén basin to Curitiba, Brazil, and could extend to Sao Paulo [***34***].

Other Central and South America

With new natural gas fields being discovered and developed in Bolivia and the completion of the Bolivia-Brazil pipeline, Bolivia is poised to become a major participant in the South American natural gas market. Bolivia has plans for considerable expansion of its pipeline infrastructure that will allow the country to supply gas to new natural-gas-fired electricity generators in surrounding countries, and discussions with Mexico raise the possibility that Bolivia could become an exporter of LNG.

Argentina is both South America's largest producer and consumer of natural gas, but it has been in a recession for the past 4 years and now is in the throes of a full

Figure 47. Major Natural Gas Pipelines in South America



Source: "Gas and Power in Latin America," *Oil & Gas Journal*, Vol. 99, No. 42 (October 15, 2001), p. 74.

economic crisis. Argentina has enormous debt that it cannot repay, and on January 6, 2002, the government announced a 29-percent currency devaluation. Before the devaluation, the government placed a cap on bank withdrawals that angered the citizenry, leading to protests and encouraging many to flee the country. Because Argentina has already defaulted on part of its $141 billion debt, it has in effect been cut off from international capital markets, and the International Monetary Fund (IMF) froze aid to Argentina in December 2001 [***35***]. Argentina's natural gas industry is entirely in the hands of the private sector and is operated within a competitive market structure. The economic crisis will certainly affect energy markets, most likely throughout South America, but the extent of the impact remains to be seen.

Chile is Argentina's largest export customer. Four pipelines currently connect the Argentine Neuquén basin with Chile, and there are plans to extend the GasAndes pipeline in central Chile, which has been in operation since 1997, to Rancagua, Chile, by the summer of 2002. In November 1999 the Gasoducto del Pacifico opened, transporting Argentine gas to industrial consumers in southern Chile's Bio Bio region. The other two Argentine-Chilean pipelines, the GasAtacama and the NorAndino, run parallel to each other and, along with Gasoducto del Pacifico, supply markets that do not yet fully utilize their capacities. The GasAtacama pipeline came online in July 1999 and primarily serves the Nopel power plant. The NorAndino pipeline came online in November 1999 and supplies two power plants.

Like Brazil, Chile's expected increase in natural gas consumption is fueled in part by a desire to become less dependent on hydropower, which is currently its largest source of electricity. Chile experienced rolling blackouts from late 1997 until well into 1999 as a result of drought [***36***]. Colombia saw less expansion of its natural gas sector in 2000 than did Brazil and Chile, but the government plans to foster future expansion in an attempt, like Brazil and Chile, to make its electricity sector less vulnerable to droughts. In early 2001, the Colombian congress was considering legislation to deregulate natural gas prices by 2003, to increase natural gas production for both domestic consumption and exports, and to support increased domestic consumption of natural gas, especially for electricity, was under consideration [***37***].

In the northern portion of South America, an active LNG market is developing. Atlantic LNG's Point Fortin facility, located in Trinidad and Tobago, became operational in 1999 with its first train of 3 million metric tons per year,[6] exporting 51 billion cubic feet to the United States and 25 billion cubic feet to Spain by the year's end. Trains 2 and 3 are under construction and will add 3.3 million metric tons per year each by the fourth quarter of 2002 and third quarter of 2003, respectively. When completed, the expansion will triple Atlantic's LNG export capacity. Venezuela is planning to enter the LNG market with two single-train facilities of 2.1 and 4.0 million metric tons annual export capacity scheduled for completion in 2004 and 2005, respectively. Petroleos de Venezuela (PDVSA), the state oil and gas company, is a partner in both terminals. In addition to its major clients, Trinidad and Tobago is currently supplying gas to the EcoElectrica facility in Puerto Rico and has also signed an agreement to send LNG to a new import terminal in the Dominican Republic as early as late 2002. This highlights the potential for increased use of imported LNG in smaller markets.

Industrialized Asia

Natural gas consumption in industrialized Asia (Australia, New Zealand, and Japan) is projected to increase by 1.9 percent per year from 1999 to 2020, much slower than the 11.2-percent annual average increase from 1970 to 1999. Industrialized Asia contributed 7 percent of the increase in world gas consumption over the past 3 decades, but its contribution over the next 2 decades is expected to fall to 2 percent.

Australia

An expanding pipeline system and continuing deregulation are moving Australia toward a more competitive domestic natural gas market. Deregulation of the gas market is being done by the states rather than central authorities, resulting in a piecemeal approach that has been blamed for the slow pace and wide variations in the domestic gas market. Reform for free and fair trade in natural gas was agreed to by the Commonwealth and all states and territories in 1997 but has yet to be fully implemented [***38***]. Gas consumption in Australia and New Zealand is projected to increase by 2.3 percent per year from 1999 to 2020 (Figure 48).

New and planned pipelines are starting to turn the once separate supply systems into a national grid (Figure 49). The creation of competing sources of supply has the potential to change the structure of the gas markets. One such project, a 3,200-kilometer pipeline from Papua New Guinea down the east coast to Brisbane, could eventually supply gas to markets in New South Wales and Victoria [***39***]; however, the project continues to languish despite the new leadership of ExxonMobil [***40***].

Australia's natural gas supply capability is expected to expand at a faster pace than domestic consumption, providing opportunities for additional exports. A fourth train is planned for the Northwest Shelf LNG venture. Sales and purchase agreements were signed with two Japanese utilities for LNG deliveries starting in mid-2004 [***41***]. A methanol plant and a gas-to-liquids (GTL)

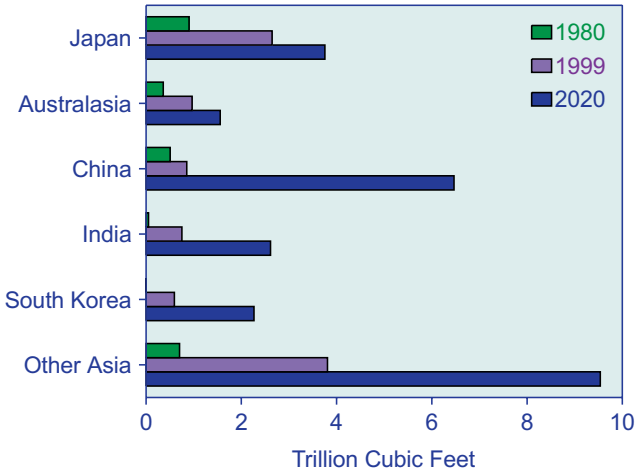
[6] A metric ton is equivalent to 48,700 cubic feet of natural gas.

facility are also being considered for the Northwest Shelf. Officials point out that the Northwest Shelf has ample gas to supply domestic as well as export projects [***42***].

Royal Dutch/Shell appears to have convinced its partners in the Greater Sunrise LNG project to develop a floating LNG facility rather than build a pipeline and a conventional onshore liquefaction plant near Darwin. Equity issues still have to be worked out, and agreements with buyers need to be secured. Greater Sunrise lies predominantly in the Australian part of the Timor Sea, but buyers remain wary because tax disputes with East Timor have halted progress on the adjacent Bayu-Undan project. Shell believes that the floating facility will be up to 40 percent cheaper than the onshore option [***43***].

The development of the 9.6 trillion cubic feet of untapped gas reserves in the Gorgon fields remains uncertain. The Gorgon partners have been trying for years to decide between an independent project and integrating their resources with the Northwest Shelf. The Northwest Shelf consortium currently believes that they can honor all contracts without the Gorgon reserves

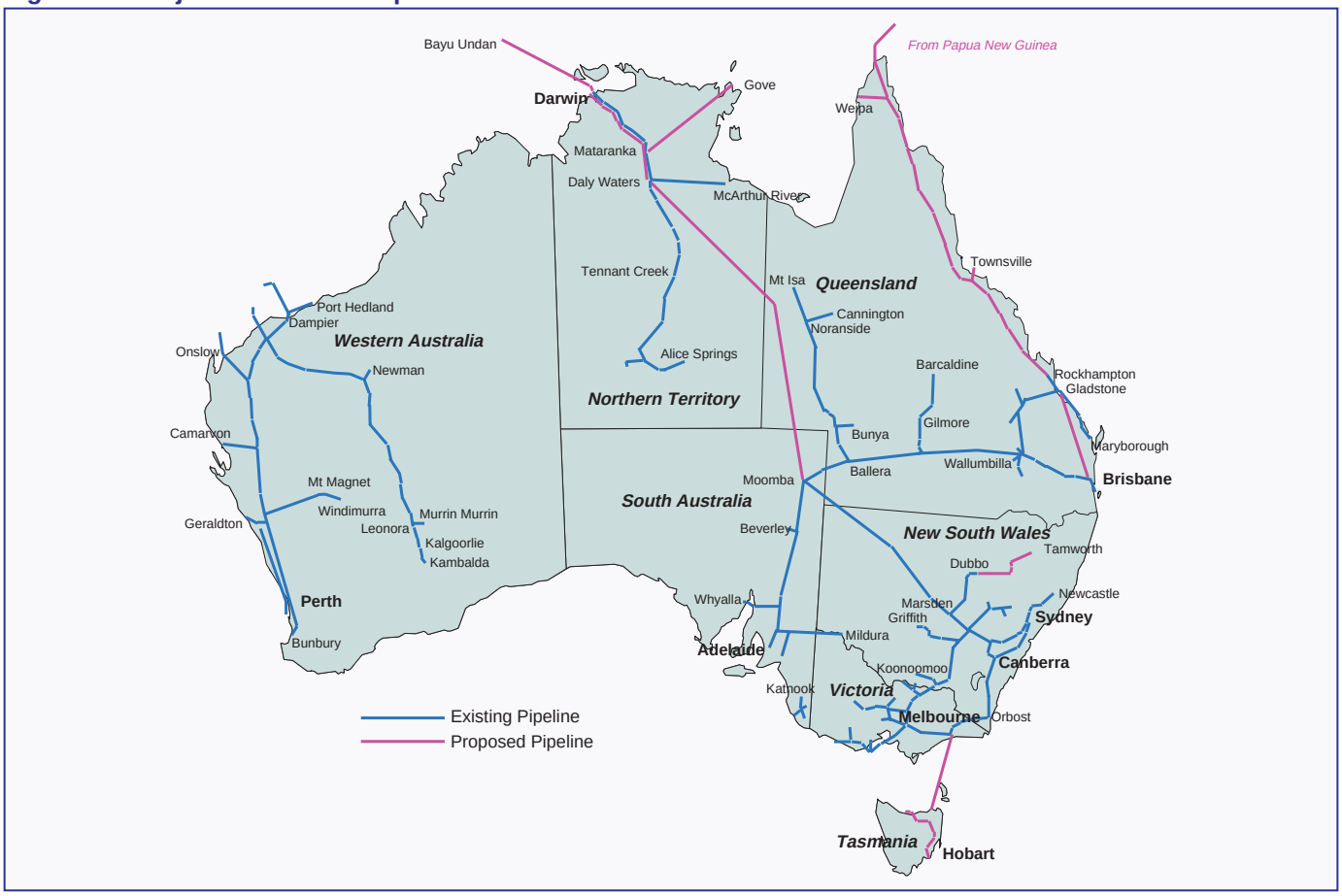
Figure 48. Natural Gas Consumption in Asia, 1980, 1999, and 2020



Note: Australasia includes Australia, New Zealand, and the U.S. Territories (Guam, Puerto Rico, and the U.S. Virgin Islands).

Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

Figure 49. Major Natural Gas Pipelines in Australia



Source: Australian Gas Association, web site www.gas.asn.au/SECTN1.htm (May 2001).

[**44**]. The China National Offshore Oil Corporation (CNOOC) signed a preliminary agreement with Chevron to study the feasibility of acquiring an equity stake in the Gorgon fields. The Gorgon gas is one of the possible sources of LNG supply for CNOOC's Guangdong LNG import project [**45**].

Japan

Natural gas demand in Japan is projected to increase by 1.7 percent per year from 1999 to 2020 (Figure 48), well below the average of 2.4 percent per year for the industrialized countries as a whole and the 3.2 percent annual average projected for world growth in natural gas use. Japan's economy continues to languish, and slow-paced deregulation of the electric power and natural gas markets is causing uncertainty about future gas demand in Japan. This uncertainty, combined with the shutdown of Indonesia's Arun facility for 7 months in 2001 (see below), may be changing the normally rigid, long-term orientation of LNG markets in Japan. For example, Chubu Electric Power has signed a framework agreement with Malaysia's LNG Tiga for emergency supplies of LNG. No minimum or maximum volumes are specified, and Chubu is required to give only 10 days notice before lifting. The price will be determined when the transaction takes place [**46**]. In addition, Japanese trading houses are starting to look outside Japan to help commercialize otherwise stranded gas reserves. The financial backing of the Japanese trading firms could speed up the development of such reserves [**47**].

Developing Asia

Developing Asia is expected to contribute 19 percent of the increase in world gas demand from 1999 to 2020. The growth of 14.9 trillion cubic feet over the forecast period is slightly higher than that projected for North America. The region includes countries that are major producers of natural gas and LNG as well as rapidly expanding gas-consuming countries.

China

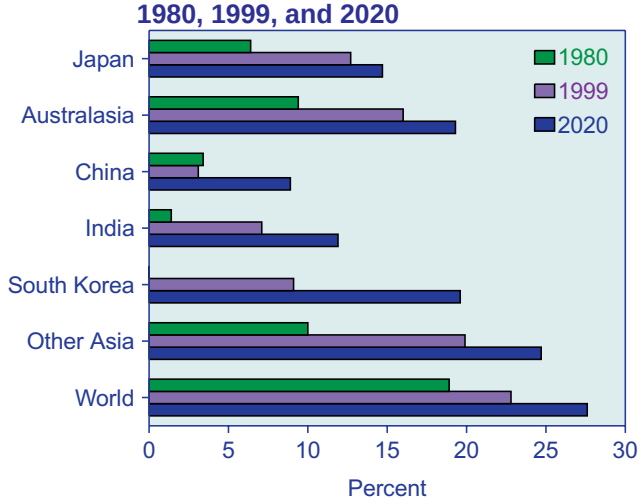
Natural gas provided 23 percent of world energy demand in 1999 but in China only 3 percent of energy demand was met by gas. Natural gas consumption in China is projected to increase by 10.1 percent per year from 1999 to 2020, raising the natural gas share of China's energy consumption to 9 percent by 2020 (Figure 50).

Environmental concerns in China are prompting movement toward gas and away from coal and oil, and energy security concerns are promoting the development of domestic gas supplies and the expansion of China's gas infrastructure. In early 2001, China's State Council approved a huge, $12 billion project to develop gas reserves in the remote western part of the country and move the gas east by pipeline to Shanghai and other Yangtze Delta cities [**48**] (see box on page 59). PetroChina completed the Sebei Lanzhou gas pipeline in September 2001, traversing a harsh natural environment. The pipeline has the capacity to move 141 billion cubic feet of gas annually from the Qaidam Basin to Lanzhou [**49**]. Supplying gas to Lanzhou has been a priority because it has the highest levels of sulfur dioxide and particulates in China and is considered one of the most polluted cities in the world [**50**].

In November 2001, PetroChina signed a contract to sell gas to the Wuhan municipal government. The gas is to be delivered through the proposed Zhong-Wu pipeline, using reserves from the Sichuan and Chongqing areas. The pipeline is expected to have an installed capacity of 3 billion cubic meters per year and provide gas to more than a dozen cities in the region. Wuhan agreed to a "take-or-pay" contract, with volumes increasing from 7 billion cubic feet in the first year to 42 billion cubic feet in the fifth year of operation. The central government is requiring PetroChina to enter take-or-pay contract deals with the cities along the pipeline route [**51**].

While China is promoting the expansion of domestic gas supplies, the development of an LNG import facility in Guangdong province is also proceeding. BP Amoco won the right to build the terminal but not necessarily the right to supply LNG to the facility. Both the Tangguh project in Irian Jaya, Indonesia, and the Greater Sunrise project in the Timor Gap are targeting the Guangdong

Figure 50. Natural Gas Share of Total Energy Consumption in Selected Asian Countries and the World, 1980, 1999, and 2020



Note: Australasia includes Australia, New Zealand, and the U.S. Territories (Guam, Puerto Rico, and the U.S. Virgin Islands).

Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

China's West-to-East Natural Gas Pipeline

Supplying natural gas to the industrial urban centers of eastern China, notably Shanghai, remains an important priority for the Chinese government. On March 25, 2000, China formally announced plans to build a massive cross-country pipeline that would transport natural gas from the Tarim basin in the west to Shanghai in the east. The pipeline would pass through seven provinces—Gansu, Ningxia, Shaanxi, Shanxi, Henan, Anhui, and Jiangsu—before reaching Shanghai. Construction of the 2,584-mile pipeline was originally slated to begin in September 2001 but has been postponed because contract negotiations between the government and the foreign companies that will be participating in the project have not been finalized.[a] The Chinese government still expects that the line will be completed before the end of 2003, but the date will depend largely on whether construction begins soon.

The West-to-East pipeline would initially deliver 424 billion cubic feet of natural gas per year to the eastern markets. Shanghai is scheduled to receive the major share, some 350 billion cubic feet per year, with the balance supplied to other provinces along the pipeline route (see map). The natural gas supplied is eventually to be increased to 706 billion cubic feet per year.[b] Thirty percent of total potential Chinese production capability of natural gas and 47 percent of the potential supply available to move between Chinese regions in 2010 is expected to originate in west China. These levels would justify the West-to-East gas pipeline, but China is also developing plans to import liquefied natural gas (LNG), as well as plans for other pipelines. The most prominent projects are the Guangzhou LNG project and the natural gas pipelines from Irkutsk in Siberia and Sakhalin in far eastern Russia.

(continued on page 60)

[a]M. Hurle, "Energy Sector Analysis: China: Mega Pipeline Facing Delays," *World Markets OnLine*, web site www.worldmarketsonline.com (October 9, 2001).

[b]Fesharaki Associates Consulting & Technical Services (FACTS), Inc., *China's Natural Gas to 2015* (Honolulu-Singapore, October 2000), p. 4-22.

China's West-to-East Natural Gas Pipeline (Continued)

The share of natural gas in China energy consumption is currently very low, estimated at 3 percent in 1999, compared with 10 percent in the rest of developing Asia and 23 percent in the rest of the world. China has been adding significant amounts of natural gas reserves over the past decade, and current reserves are estimates at 38.8 trillion cubic feet.[c] China considers an acceleration of natural gas production to be an attractive policy for switching to clean-burning fuels, both on environmental grounds and to tap domestic gas resources in substitution for domestic coal and imported oil. The *IEO2002* reference case forecast indicates that China's natural gas demand is expected to reach 2.8 trillion cubic feet by 2010 and 6.4 trillion cubic feet by 2020. A more optimistic, full-fledged fuel-switching policy could boost demand to 3.4 trillion cubic feet as early as 2010, with 53 percent going into power generation, 21 percent consumed in the chemical sector, and 25 percent used as city fuel.[d]

Although China sees the importance of developing domestic sources of natural gas in order to enhance the security of energy supplies, the cross-country pipeline is not necessarily economically sound, nor are its potential supplies currently needed to meet the low level of demand in eastern China. Environmental quality has been a significant concern behind the government's determination to implement the West-to-East project. Major cities in China frequently have been ranked high in various top 10 lists of the most polluted cities in the world. Decades of expansionary coal use have resulted in environmental degradation, which needs urgent remediation. Estimates by some independent observers and by Chinese officials put the direct economic losses caused by pollution at approximately $100 billion per year, and some analysts claim that China must now spend $20 billion per year just to prevent pollution from rising above current levels.[e]

For Shanghai, which is the target market for many large pipeline proposals, the high cost of supplying gas from western China largely reflects the cost of assembling gas from the various western supply basins (Tarim, Junggar, Turpan-Hami, and Qaidam) at a common point. From there, a large diameter pipeline could be used to connect with the Ordos basin and on to Shanghai. The delivery costs to Shanghai from west China gas would be much higher than the cost of importing Irkutsk gas from eastern Siberia. As a result, if the Chinese government were basing its decisions about constructing the West-to-East pipeline solely on the cost of transporting the gas to market, Chinese policy makers would choose Irkutsk over western China as the source of remote gas supply.[f]

While most of the natural gas industry in China continues to function under quotas and supply allocations, a parallel pricing regime has been created for all new foreign-invested projects. The new pricing structure attempts to create a mechanism to reflect the true economic cost of projects and an adequate gas transportation tariff to secure a profit margin for the developers. However, recent examples show that when the combination of the gas price and the pipeline tariff proposed by developers differs significantly from the maximum affordable citygate price, the Chinese gas regulators tend to adjust the total price by cutting the pipeline tariff. The Ordos-Beijing pipeline, owned by PetroChina and the Beijing city government, received approximately half its requested tariff (12.71 yuan, or $1.41, per cubic foot, versus a proposed 26.12 yuan, or $3.18); and the Zhongxian-Wuhan pipeline, partially financed by a foreign developer, was approved for a 9.53 yuan ($1.06) per cubic foot tariff despite a proposed tariff of 12.71 yuan per cubic foot. In both cases, the developers decided to proceed despite concerns that the pipeline project was not economically viable.[g]

Because of the project size and distance from market, the West-to-East gas pipeline project more nearly resembles import pipelines than those from domestic basins such as the Ordos and Sichuan, which serve the northeastern markets in and around Beijing. For example, the West-to-East China pipeline investment is larger than that required to supply a similar amount of gas from Sakhalin (far east Russia) and is nearly as large an investment as the Irkutsk (eastern Siberia) project and its giant Kovyktinsk field, which has double the supply capacity of west China fields.[h]

(continued on page 61)

[c]DRI-WEFA, "Energy Monitor: Asia," *World Energy Service Asia/Pacific Outlook* (Lexington, MA, October 2001).

[d]Lan Quan and Keun-Wook Paik, *China Natural Gas Report* (London, UK: Xinhua News Agency, Beijing and Royal Institute of International Affairs, 1998).

[e]Cambridge Energy Research Associates, *Onshore Gas Opportunities in China: A New Era?* (Cambridge, MA, February 2000), p. 3.

[f]Asia Pacific Energy Research Center, *Natural Gas Infrastructure Development: Northeast Asia, Costs and Benefits* (Tokyo, Japan, March 2000), p. 113.

[g]Cambridge Energy Research Associates, *Betwixt and Between: China's Natural Gas Industry under Commercial Principles* (Cambridge, MA, February 2001), p. 6.

[h]Asia Pacific Energy Research Center, *Natural Gas Infrastructure Development: Northeast Asia, Costs and Benefits* (Tokyo, Japan, March 2000), p. 111.

terminal. BP Amoco and the Indonesian state oil company, Pertamina, are promoting Tangguh; Royal Dutch/Shell is leading the Greater Sunrise project along with Woodside, Phillips, and Osaka Gas [***52***]. The Gorgon project in Australia is considered a long shot for supplying Guangdong, given technical problems related to its high carbon dioxide content [***53***].

In addition to the Guangdong facility, CNOOC signed an agreement with the Fujian provincial government to build a 2 million metric ton LNG receiving terminal. CNOOC would take responsibility for the terminal and an attached trunk pipeline, and the Fujian government would take care of the provincial distribution network. A detailed study must be done and submitted to the State Development Planning Commission for approval, but CNOOC would like to begin operation by 2005 or 2006 [***54***]. Fujian province is located on the south China coast between the LNG facility planned for Guangdong and the West-East pipeline that is intended to extend to Shanghai.

India

India has also been the target of intense interest by LNG producers as a country with great growth potential. Many projects have been proposed, but the collapse of the Dabhol project, uncertainties concerning LNG policies, and problems associated with selling costly gas to financially troubled state power distributors have slowed the advance of LNG import projects. Natural gas demand growth is projected to remain strong, however, and some projects are making progress.

China's West-to-East Natural Gas Pipeline (Continued)

Another issue of concern to the West-to-East pipeline developers is that China currently does not have an adequate distribution network to send massive natural gas supplies to individual users in Chinese cities, although progress is being made in improving the situation. In fact, because of the lack of distribution networks, many of the pipelines already completed are running at rates that are lower than their design capacity. For instance, the 536-mile Shaan-Jing pipeline connecting Jingbian in Shaanxi Province with Beijing, completed in September 1997, still is operating below capacity. Although the Shaan-Jing pipeline was designed to transport 194 million cubic feet per day, the initial delivery was only 106 million cubic feet per day. Even at that level, Beijing's actual gas consumption was much lower.

The 480-mile Yacheng-Hong Kong Pipeline, the longest undersea pipeline in Asia and the second largest in the world, was completed in 1996. It connects the offshore Yacheng 13-1 gas field with Hong Kong power plant at Black Point. The total cost of the pipeline was $1.1 billion. Because Hong Kong cannot consume all the gas delivered by contract, it must flare some of it under a "take-or-pay" clause. Other completed pipelines have encountered the same problem: extremely low utilization rates at the initial stage, because the target cities or industrial users were not ready.[i]

The future of natural gas in China's electricity generation sector—the largest targeted market for the West-to-East pipeline gas—is also uncertain. A number of factors could put the natural gas at a disadvantage relative to other fuels. One is that the power sector, without proper environmental regulations such as taxing heavy polluters, would not expand the use of natural gas for electricity generation. Coal would remain the preferred fuel because of its ability to compete on cost. Secondly, the retail price of natural gas in Shanghai would have to compete with cheaper imports of LNG. The latter may occur if the Guangzhou LNG project is deemed a success and another terminal is built near Shanghai.[j] Various governmental studies insist that the end-user prices of the pipeline gas will be competitive with LNG; however, the calculations are based largely on the assumption that pipeline utilization rates will be high. The cost will be much higher if the pipeline is underutilized.

To finance the West-to-East pipeline project, the Chinese government has announced that it would allow foreign investors to hold majority stakes in the pipeline, which will cost an estimated $4.8 billion to build. China will also open potentially lucrative areas of gas development and marketing to foreign companies, which will require an additional $13.2 billion in investment.[k] PetroChina, the official sponsor of the West-to-East project, short-listed a foreign consortium, which is led by ExxonMobil, Royal Dutch/Shell, and BP. However, BP decided to withdraw from the project in early September 2001, in the face of a demanding deadline to submit its final investment proposal. BP's withdrawal has underscored doubts that the 2,584-mile natural gas pipeline's commercial potential matches its political importance.

[i]Fesharaki Associates Consulting & Technical Services (FACTS), Inc., *China's Natural Gas to 2015* (Honolulu-Singapore, October 2000), p. 4-16.

[j]"Markets, Prizes, and Briefs," *Petroleum Intelligence Weekly*, Vol. 40, No. 24 (June 11, 2001), p. 11.

[k]"China: BP Pulls Out of the 4,000 km West-East Pipeline Project," *CEDIGAS NEWS REPORT*, Vol. 40, No. 38 (September 29, 2001), p. 7.

Enron's Dabhol project had collapsed long before the company itself (see box on page 135). The Maharashtra State Electricity Board accused Enron of overcharging and refused to pay for the power from Dabhol. The Enron-controlled Dabhol Power Company then defaulted on interest payments to international lenders on the gas-fired, 1,440 megawatt second phase of the project, which was 90 percent complete [***55***]. A 2.5 million ton LNG receiving terminal was said to be roughly 85 percent complete. Indian financial institutions are laying claim to the Enron assets, but their success at taking over the assets remains unclear [***56***].

A few LNG projects are making progress. National Thermal Power Corporation, India's biggest power producer, invited bids to supply 4 million tons per year of LNG to its proposed gas-fired power plants. Qatar, Oman, and Iran are considered frontrunners. A potential stumbling block, however, is the shortage of pipelines to move the gas to the relatively distant locations of the generating facilities. Petronet LNG, which is planning to begin importing gas at its 5 million ton LNG facility at Dahej in Gujarat in December 2003, is also preparing to select a contractor to build a 2.5 million ton per year terminal at Kochi in Southern India [***57***].

LNG policy confusion and backpedaling on market liberalization could complicate LNG projects. Policy differences among ministries are delaying the adoption of an integrated policy on importing, consuming, and transporting LNG. The government is considering a proposal to free natural gas prices along with oil prices in April 2002, but because of opposition by the Ministry of Finance, natural gas prices may be only partially freed. Another measure under consideration would require 26 percent Indian ownership in any venture shipping LNG to India, gradually rising to 50 percent in 5 years. In order to ensure domestic control, the government is also likely to insist on free-on-board (f.o.b.) contracts that obligate the buyer to arrange for transporting the product [***58***].

South Korea

Natural gas demand in South Korea is expected to grow by 6.6 percent per year from 1999 to 2020. Despite an economic slowdown, gas consumption jumped by about 13 percent in the first half of 2001. The surge in demand occurred in the residential and industrial sectors as well as power generation, reflecting a rapidly expanding gas grid. City gas demand is expected to remain strong as progress is made on a nationwide transmission system. The increase in gas demand came despite LNG prices that topped $5 per million Btu when oil prices were high. LNG prices are beginning to ease, but the responsiveness of gas demand to price was not evident in the first half of the year [***59***].

Other Developing Asia

Indonesia is the largest LNG producer in the world, but unrest in the province of Aceh resulted in the shutdown of the Arun LNG facility for 7 months in 2001. The shutdown left Korea Gas Corporation (Kogas) and Japan's Tohoku Electric searching for replacement supplies. Because South Korea's summer gas consumption is less than half of the winter level, Kogas was able to get by with an occasional cargo from Bontang to supplement its contracted supplies from the Middle East and Malaysia. Tohoku received several replacement cargoes from the Bontang facility and from Malaysia [***60***].

The Arun facility was commissioned in 1978 and was expected to reach the end of its producing life over the next decade or so due to declining gas reserves. Two trains were shut down in 2000 [***61***]. But the problems in Aceh may speed the scaling down of Arun. Two Japanese utilities indicated that they may cut imports from Arun from 3.5 million tons per year to 1 million tons per year when their 20-year contracts expire in 2005 [***62***].

Indonesia is planning to expand the LNG facility at Bontang and to build a new plant at Tangguh in Irian Jaya, but the instability could hurt the ability of these projects to secure buyers. Indonesian officials claimed that Japanese utilities and CPC Taiwan have committed to take over 3 million tons per year from Tangguh, but both CPC and the Japanese utilities denied any keen interest [***63***]. El Paso Natural Gas, a U.S. company, was seeking to secure LNG supplies from the Timor Gap, but with that project on hold El Paso is showing interest in Tangguh. An independent power project from the Philippines, GNPower, signed a letter of intent to buy 1.3 million tons per year from Tangguh even though the Malampaya fields just started to deliver gas onshore. Some sources expect the Malampaya gas to be more expensive than imported LNG [***64***].

Malaysia is expanding its Bintulu LNG facility without the long-term contracts in place that normally accompany an LNG project. The 6.8 million ton per year expansion will increase total capacity to 23 million metric tons per year, making Bintulu the largest LNG producing facility in the world. The project, which is being jointly developed by Petronas and Royal Dutch/Shell, had a letter of intent for 2.6 million tons per year from Enron's subsidiary in India, but that is highly unlikely at this point. That leaves a firm contract for only 0.9 million tons per year with Tohoku Electric. Malaysia is desperately seeking Japanese and South Korean customers to absorb the gas and could be a large contributor to the nascent LNG spot market [***65***].

While the Trans-ASEAN Gas Pipeline remains just a concept on paper, small pieces of what could eventually be a gas pipeline grid in Southeast Asia are being

developed. In January 2001, gas began to flow from Indonesia's West Natuna fields to Singapore, and in February a contract was signed to bring gas to Singapore from Indonesia's South Sumatran fields. The contract calls for gas to begin flowing in July 2002 and continue for 20 years. In March, Indonesia signed a contract with Malaysia to supply 1.5 trillion cubic feet of gas over a 20-year period from the West Natuna fields into the Malaysian peninsular network [***66***].

Delays continue for a planned gas pipeline from the Thailand-Malaysia joint development area (JDA) to southern Thailand and on to northwest Malaysia. Villagers at the proposed landing point for the pipeline protested that it would inflict environment damage and affect fishing in the area. Thai authorities rejected the project's environmental impact assessment. The pipeline was to have been completed by mid-2002 but now is not expected until the end of 2003 at the earliest [***67***]. A connection to Thailand's offshore gas fields and transmission system to the north of the JDA is also being considered, which would allow gas to be delivered to Bangkok [***68***].

Myanmar gas can now reach demand centers along Thailand's main gas transmission line following the completion of a 60-mile pipeline connection from Ratchaburi to Wang Noi. This should allow Thailand to take all of the gas specified in its contract with Myanmar. The reduction in electricity and gas demand after the 1997 financial crisis left Thailand with more gas than could be used at the Ratchaburi generating plant.

The Philippines inaugurated the Malampaya gas-to-power project in October 2001 and unveiled plans for expanded natural gas use. The privatization plan of the state-owned power company, the National Power Corporation, is supposed to include the conversion of certain plants to gas-fired power. A pipeline is planned to transport gas from Batangas to Manila (the so-called Batman project) to switch a power plant that is currently burning diesel to natural gas. The Malampaya infrastructure currently has enough capacity to fuel up to 4 gigawatts of power generation capacity, and 2.7 gigawatts are under contract [***69***].

The new government of Prime Minister Begum Khaleda Zia in Bangladesh is considering a gas export pipeline to India, although opposition remains fierce. Economic realities are compelling the deliberation, especially given foreign exchange difficulties that have halted payments totaling $54 million each to Shell and Unocal for gas purchased over the past few months. Unocal indicated in its proposal for a 500 million cubic feet per day pipeline to Delhi that the Bangladeshi government could receive $3.7 billion in revenue over the next 20 years [***70***]. Demonstrations and street protests followed indications that the government was considering natural gas exports [***71***].

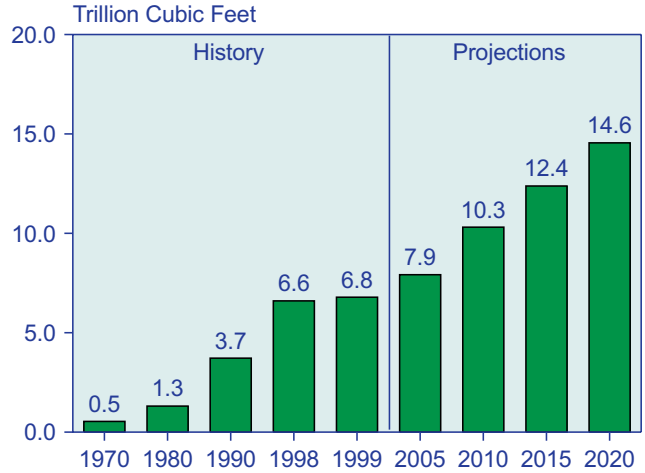
East Timor and Australia agreed to a 90/10 split of revenues from natural gas development in the Timor Gap. The original agreement, negotiated when East Timor was part of Indonesia, called for a 50/50 split of revenues [***72***]. The initial encouragement that the agreement gave to gas development in the region quickly dissipated when Phillips and its partners in the Bayu-Undan project indefinitely deferred development until certain legal, fiscal, and taxation issues arising from the new agreement are resolved [***73***].

Middle East

As of January 1, 2002, the Middle East's reserves of 1,975 trillion cubic feet were essentially equal to the FSU's 1,972 trillion cubic feet, but the region's production and consumption were less than one-third of those in the FSU. The Middle East more than doubled production between 1990 and 1999 and nearly doubled consumption. The region increasingly seeks to develop domestic gas markets, and rapid growth is expected in the *IEO2002* forecast (Figure 51). Consumption is projected to more than double, growing to 14.6 trillion cubic feet in 2020 from 6.8 trillion cubic feet in 1999, an average annual rate of 3.7 percent. The most significant reserves in the Middle East are held by (in order of size) Iran, Qatar, Saudi Arabia, and the United Arab Emirates (UAE), each holding in excess of 200 trillion cubic feet.

Because the bulk of Iranian natural gas reserves are located in nonassociated fields and have not been

Figure 51. Natural Gas Consumption in the Middle East, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

developed, Iran has tremendous potential for expansion of both its internal and export natural gas markets. Additionally, with much territory yet to be explored, Iran continues to make significant new discoveries. Most of Iran's reserves are in the southern part of the country, and Iran imports natural gas from Turkmenistan to satisfy demand in the northern part of the country. The country is also looking into the possibility of importing from Azerbaijan. Currently, Iran imports relatively small amounts of its gas, about 4 percent of its total natural gas consumption. Natural gas accounts for approximately 44 percent of Iran's total energy consumption, but the government plans to invest billions of dollars in the gas sector during its current Five-Year Development Plan, hoping to advance both its domestic and its export markets.

Over the past year or so, Iran has made a number of significant gas finds, though none that come close in magnitude to its South Pars field. South Pars is Iran's largest nonassociated natural gas field, projected to begin production in 2002. It is estimated to contain approximately 280 trillion cubic feet of gas, much of which is considered to be recoverable, and more than 17 billion barrels of liquids. South Pars is geologically an extension of Qatar's 241 trillion cubic feet North Field. Gas from South Pars is slated to be shipped north via the planned IGAT-3 pipeline, and possibly an additional IGAT-4 line, and then reinjected to boost oil output in mature fields that are currently in decline.

Iran's South Pars gas could also be exported, both by pipeline and possibly by tanker as LNG. In addition to the 280 trillion cubic feet in the South Pars field, a separate North Pars field contains an additional 48 trillion cubic feet. TotalFinaElf, Russia's Gazprom, and Malaysia's Petronas have jointly agreed to explore South Pars and to help develop the field during Phase 2 and 3 of its development. Phase 1, which is being handled by Petropars, has been delayed several times and now is scheduled for partial completion by the end of 2002. The development is expected to proceed through 12 phases, with phases 9 and 10 expected to supply the domestic market and phases 11 and 12 slated for LNG export [***74***].

Iran has reportedly discussed natural gas exports with Kuwait and the United Arab Emirates. To date, it has provided exports only to Turkey. In 1996, Iran agreed to supply Turkey with natural gas for a period of 22 years. Originally slated to commence in 1999 at a rate of 300 million cubic feet per day and increase to a level of 1 billion cubic feet per day in 2005, the flow of gas from the northwestern Iranian city of Tabriz to Ankara was postponed until September 2001 after Turkey requested a delay due to economic problems that prohibited it from completing its portion of the pipeline. A further delay came when Turkey maintained that a metering station on the Iranian side was not ready for operation. Flows finally began on December 11, 2001.

Turkey's growth in natural gas consumption is proceeding at a much more rapid rate than its growth in production, and the country is expected to increase its imports from neighboring countries significantly. Currently Turkey is supplied by only Russia and Africa. Russian pipeline imports account for approximately 70 percent of Turkey's imports, with additional new pipeline supplies from Iran and LNG from Algeria and Nigeria accounting for the rest of its gas supply. Although it has had many recent gas finds, most of Turkey's gas is reinjected to enhance oil recovery, and domestic production is not expected to contribute significantly to internal consumption.

Across the border from Iran's South Pars is Qatar's North Field, the largest nonassociated gas field in the world. Internal consumption in Qatar declined by slightly over 9 percent in 2000, but its 2000 production exceeded 1999 production by 20 percent. The additional production was primarily to serve Qatar's rapidly growing export market. Almost half of Qatar's production was exported in 2000, all in the form of LNG. In 2000, Qatar was the fourth largest exporter of LNG in the world, behind Indonesia, Algeria, and Malaysia. Its major customers were Japan and South Korea, but the United States, Spain, Italy, and France also received cargos from Qatar. Investment in LNG liquefaction facilities in Qatar has been significant. The first facility was completed in 1997, with three trains and a capacity of 7.7 million metric tons per year, and the second was completed in 1999, with two trains and a capacity of 6.6 million metric tons per year. There are plans to expand the second facility by 8.9 million metric tons per year by adding two additional trains.

Qatar is expected to play a major role in increasing natural gas use in the Middle East. According to current plans, gas will be exported by a new pipeline from Qatar's North Dome field to Abu Dhabi, Dubai, and Oman, with a possible future link to India. The planned pipeline, to be developed by Qatar's Dolphin Energy, Ltd. (DEL), will be the first cross-border pipeline in the Middle East. According to a Dolphin Energy press release on January 7, 2002, "the Dolphin project will complement the gas operations of Abu Dhabi National Oil Company (ADNOC) and meet demand for gas in the UAE, especially from the power generation sector, which is rising by between 10-12 percent a year" [***75***]. This will supplement Abu Dhabi's own production, which is not expected to increase as rapidly as its consumption, despite its plentiful natural gas resources. The pipeline will also provide opportunities to develop new industries in both Qatar and the UAE. Dolphin expects deliveries to its customers in the UAE to begin in

2005. If its projection of delivering 3 billion cubic feet per day is met, it would account for close to 10 percent of the world's pipeline trade.

The UAE contains extensive gas reserves, over 90 percent of which are in Abu Dhabi. LNG has been exported from Abu Dhabi's Das Island facility since 1977. The facility was expanded in 1994 and now consists of three trains with a total capacity of 3.3 million metric tons per year. Japan is the primary customer for Abu Dhabi's LNG exports. In May 2001 a pipeline from Abu Dhabi to Dubai (Abu Dhabi and Dubai are the two largest Emirates) began operating, supplementing Dubai's natural gas supply. Before May, Dubai was served entirely by Sharjah, another of the Emirates. UAE is intent on expanding its natural gas market and has invested heavily in moving to natural-gas-fired power plants and industry. It is also a partner in the Dolphin project to deliver gas from Qatar to the UAE, Oman, and potentially India.

Approximately two-thirds of Saudi Arabia's currently proven gas reserves consist of associated gas. Before 1984, when Saudi Arabia's Master Gas System (MGS) was completed to deliver gas to the industrial cities of Yanbu and Jubail, all of Saudi Arabia's natural gas was flared. While Saudi Arabia's gas sector has not shown significant growth in recent years, demand increases are anticipated, and Saudi Arabia has been promoting foreign investment in its gas sector. In May 2001, Saudi Arabia selected companies to participate in a $25 billion "Saudi Gas Initiative," the first major reopening of Saudi Arabia's upstream hydrocarbons sector to foreign investment since nationalization in the 1970s. The purpose of the initiative, which consists of three "core ventures," is to integrate upstream gas development with downstream petrochemicals and power generation. Companies selected for the three core ventures under the Gas Initiative are (1) South Ghawar: ExxonMobil, Shell, BP, Phillips; (2) Red Sea: Exxon plus an Enron / Occidental partnership; and (3) Shaybah: Shell, Total, Conoco.

Core Venture 1 will include exploration, pipelines, two gas-fired power plants, two petrochemical plants, and two desalination units. Core Venture 2 will involve exploration and development in and along the coast of the Red Sea in northwestern Saudi Arabia and the construction of a petrochemical plant and a power station. Core Venture 3 will involve exploration near Shaybah in the Rub al-Khali ("Empty Quarter") of southeastern Saudi Arabia, development of the Kidan gas field, laying of pipelines from Shaybah to the Haradh and Hawiyah gas treatment plants east of Riyadh, and construction of a petrochemical plant in Jubail. Additional gas use is being encouraged for the country's growing petrochemical industry, for electricity generation, for desalination plants and other industrial facilities, and as a replacement for oil burning. The use of gas instead of oil domestically is intended to help free up additional crude oil for export.

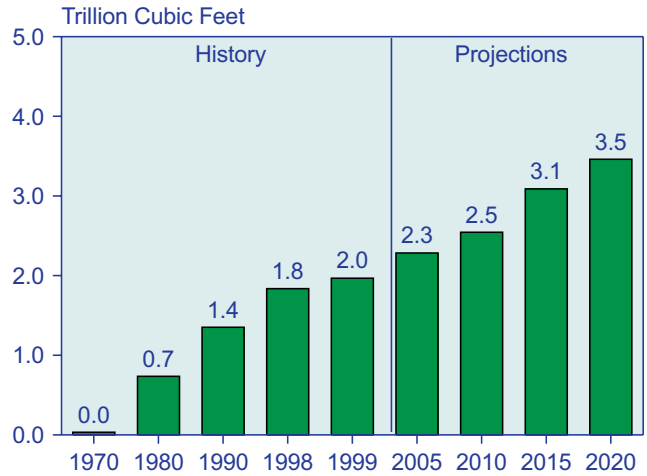
Africa

Africa's gas reserves, estimated at 394 trillion cubic feet, account for 7.4 percent of global reserves. Algeria and Nigeria account for 284 trillion cubic feet of reserves, or 72 percent of the total. Egypt and Libya account for another 21 percent, with the remainder of Africa containing only 7 percent of the continent's total reserves. Thus, gas exploration and production activities, along with export projects and plans to increase domestic use, are concentrated in north and west Africa.

Africa accounts for about 5 percent of the world's natural gas production but only 2 percent of the world's consumption. In 2000, Africa provided 17.4 percent of the world's natural gas exports, including 9.1 percent of pipeline exports and 41.0 percent of LNG exports [***76***]. Two-thirds of the total exports came from Algeria. Africa's natural gas consumption is increasing significantly, and the *IEO2002* reference case projects average increases of 7.4 percent per year, from 2.0 trillion cubic feet in 1999 to 3.5 trillion cubic feet in 2020 (Figure 52).

In Nigeria, increased associated gas production has developed as a result of increased crude oil production and intensified efforts to reduce gas flaring. Gas is liquefied at the Bonny Island facility, which has been in operation since 1999, and shipped to markets that include the United States, Spain, Italy, France, and Turkey. Two trains are currently operational with a combined

Figure 52. Natural Gas Consumption in Africa, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

capacity of 5.9 million metric tons per year. A third train, scheduled to come online in 2002, will provide another 2.95 million metric tons per year. A third expansion, proposed to come online in 2005/2006, will, if built, add two trains and an additional capacity of 8.0 million metric tons per year [***77***]. In 2000, Nigeria accounted for approximately 10 percent of Africa's LNG exports, and its exports are expected to grow as the Bonny Island facility expands.

Algeria is the continent's most developed export market, with 40 percent of its production being exported by pipeline to Italy, Spain, Portugal, Slovenia, and Tunisia and 37 percent exported as LNG to France, Belgium, Spain, Turkey, Italy, the United States, and Greece. The strong LNG market that has developed in Africa includes, in addition to Algeria and Nigeria, one operational facility in Libya, one facility under construction in Egypt and two proposed, and a proposed facility south of Nigeria in Angola [***78***]. Africa currently has 12 trains operational, with a combined capacity of 13.5 million metric tons per year. Three additional trains under construction will add another 11.8 million metric tons per year. Although Libya was the first to export LNG, beginning in 1970, Algeria was not far behind, opening its first facility in 1972. Nigeria entered the market in 1999 with the completion of its Bonny Island facility, and Egypt plans to enter in 2004 with its Damietta facility. Algeria has proposed locating another facility along the Mediterranean coast.

References

1. BP p.l.c, *BP Statistical Review of World Energy 2001* (London, UK, June 2001), p. 3, web site www.bp.com.
2. BP p.l.c, *BP Statistical Review of World Energy 2001* (London, UK, June 2001), p. 20, web site www. bp.com.
3. Qatar National Bank, *Qatar Economic Review* (Doha, Qatar, March 2002), pp. 24-25, web site www.qatarbank.com.
4. Energy Information Administration, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), p. 83.
5. U.S. Department of Energy, Office of Fossil Energy, *Natural Gas Imports and Exports* (Washington, DC, Fourth Quarter 2000), p. iii.
6. U.S. Department of Energy, Office of Fossil Energy, *Natural Gas Imports and Exports* (Washington, DC, Fourth Quarter 2000 and Third Quarter 2001).
7. "LNG May Sway US Prices," *World Gas Intelligence*, Vol. 13, No. 4 (January 23, 2002), p. 1.
8. "Maritimes Expects To Grow to 1 Bcf/d, Holds Open Season," *Natural Gas Intelligence* (September 3, 2001), p. 6.
9. According to an article in the December 4, 2001, *Oil and Gas Journal*, p. 66, spot market sales worldwide dropped to 5.4 percent in 2000, compared with 8.8 percent in 1999.
10. "El Paso Requests Settlement Judge; Elba Island LNG Expansion Sought," *Inside FERC's Gas Market Report* (September 14, 2001), p. 16.
11. U.S. Department of Energy, Office of Fossil Energy, *Natural Gas Imports and Exports* (Washington, DC, Fourth Quarter 2000).
12. "Mexican Output Drive; Natural Gas," *World Gas Intelligence*, Vol. 12, No. 27 (September 12, 2001), p. 5.
13. "El Paso Files To Expand U.S.-Mexico Border Capacity," *The Energy Report*, Vol. 39, No. 36 (September 3, 2001).
14. "El Paso Applies To Expand Export Capacity to Mexico," *Natural Gas Intelligence* (September 3, 2001), pp. 6-7.
15. "Sempra, CMS Plan Baja LNG Terminal," *Natural Gas Week*, Vol. 17, No. 41, p. 2.
16. "Bolivia Energy: Mexico and Bolivia To Include Natural Gas in Trade Agreement," *Financial Times Information, Global News Wire* (September 19, 2001).
17. S. Fletcher, "Time To Change Energy Sector, Say Mexican Officials," *Oil & Gas Journal*, Vol. 99, No. 46 (November 12, 2001), p. 34.
18. "Pemex Details Plans for Burgos Service Contracts," *Platt's Oilgram News*, Vol. 79, No. 188 (September 28, 2001), p. 2.
19. M.P. Hoyt, "E&D Opportunities May Loom in Mexico's Natural Gas Industry," *Oil & Gas Journal*, Vol. 99, No. 46 (November 12, 2001), p. 48.
20. Europa: The European Union On-Line, "Institutions: Overview: Institutions of the European Union," web site www.europa.eu.int (no date).
21. Europa: The European Union On-Line, "Activities of the European Union: Energy: Internal Market in Energy: Completing the Internal Energy Market," web site www.europa.eu.int/scadplus (May 31, 2001).
22. Energy Information Administration, "Country Analysis Brief: Portugal," web site www.eia.doe.gov (March 2001).
23. "Athens (Greece)," *Encarta Encyclopedia*, web site http:encarta.msn.com (2001).
24. Energy Information Administration, "Country Analysis Brief: Greece," web site www.eia.doe.gov (September 2001).

25. Energy Information Administration, "Country Analysis Brief: Greece," web site www.eia.doe.gov (September 2001).
26. P. O'Neill, "Future Development of the Natural Gas Industry in Ireland," Presented at the Energy Ireland 2000 Conference (Dublin, June 15, 2000), web site www.irlgov.ie.
27. DRI-WEFA, *World Energy Service: Western Europe*, Vol. III (December 2000); updated online at web site www.dri-wefa.com (January 2001).
28. D. Nagel, "Gas Export Plans," in *Fundamentals of the Global LNG Industry* (London, UK: Petroleum Economist, Ltd., and Shell Gas & Power, March 2001), p. 67.
29. Zeus Development Corporation, *2001 World LNG/GTL Review* (Houston, TX, 2001).
30. Energy Information Administration, "Country Analysis Brief: Russia," web site www.eia.doe.gov (October 2001).
31. Energy Information Administration, "Country Analysis Brief: Russia," web site www.eia.doe.gov (October 2001).
32. "When Gas-Fired Power Clashes with Hydroelectricity," *World Gas Intelligence*, Vol. 13, No. 1 (January 2, 2002), p. 7.
33. Energy Information Administration, "Country Analysis Brief: Brazil," web site www.eia.doe.gov (June 2001).
34. Energy Information Administration, "Country Analysis Brief: Argentina," web site www.eia.doe.gov (October 2001).
35. "Argentina Postpones Devaluation Once Again," *Business Day* (January 11, 2002), p. 5, web site www.bday.co.za.
36. Energy Information Administration, "Country Analysis Brief: Chile," web site www.eia.doe.gov (May 2001).
37. Energy Information Administration, "Country Analysis Brief: Colombia," web site www.eia.doe.gov (March 2001).
38. Energy Information Administration, "Country Analysis Brief: Australia," web site www.eia.doe.gov (June 2001).
39. "Slow Progress to Australian National Grid," *World Gas Intelligence*, Vol. 12, No. 3 (February 8, 2001), p. 11.
40. "Australia's Big Plans for Timor Gap Gas," *World Gas Intelligence*, Vol. 12, No. 17 (July 4, 2001), p. 3.
41. "News in Brief," *Petroleum Economist* (November 2001), p. 46.
42. "NW Shelf Gas Sales," *World Gas Intelligence*, Vol. 12, No. 35 (November 7, 2001), p. 5.
43. "Sunrise Partners' New Fight," *World Gas Intelligence*, Vol. 12, No. 38 (November 28, 2001), p. 1.
44. "NW Shelf Gas Sales," *World Gas Intelligence*, Vol. 12, No. 35 (November 7, 2001), p. 5.
45. "Chevron Hatches Plan for Asian Gas Push," *World Gas Intelligence*, Vol. 12, No. 25 (August 29, 2001), pp. 2-3.
46. "Market Insight: Change Japanese Style," *World Gas Intelligence*, Vol. 12, No. 40 (December 12, 2001), p. 6.
47. "Japan Targets Tangguh," *World Gas Intelligence*, Vol. 12, No. 25 (August 29, 2001), p. 1.
48. "China Goes into Overdrive for West-to-East Gas Pipeline," *World Gas Intelligence*, Vol. 12, No. 9 (May 9, 2001), p. 8.
49. "China," *CEDIGAZ News Report*, Vol. 40, No. 41 (October 19, 2001), p. 9.
50. "China Courts Investors for Giant Gas Projects," *Petroleum Intelligence Weekly*, Vol. 40, No. 20 (May 14, 2001), pp. 3-4.
51. "China," *CEDIGAZ News Report*, Vol. 40, No. 47 (November 30, 2001), p. 7.
52. "China, El Paso Rattle Pacific LNG Scene," *Petroleum Intelligence Weekly*, Vol. 40, No. 43 (October 22, 2001), p. 5.
53. "Tale of Two LNG Schemes," *World Gas Intelligence*, Vol. 12, No. 32 (October 17, 2001), p. 1.
54. "China," *CEDIGAZ News Report*, Vol. 40, No. 46 (November 23, 2001), p. 2.
55. "Default at Dabhol," *World Gas Intelligence*, Vol. 12, No. 29 (September 26, 2001), p. 5.
56. "Trying To Untie Far Flung Enron Assets," *World Gas Intelligence*, Vol. 12, No. 39 (December 5, 2001), p. 3.
57. "India LNG Prospects Suddenly Look Up," *World Gas Intelligence*, Vol. 12, No. 37 (November 21, 2001), p. 1.
58. "India's LNG Policy," *World Gas Intelligence*, Vol. 12, No. 39 (December 5, 2001), p. 5.
59. "Market Insight: Korea's Persistent Growth," *World Gas Intelligence*, Vol. 12, No. 23 (August 15, 2001), p. 6.
60. "Hunt for Arun Replacements," *World Gas Intelligence* Vol. 12, No. 14 (June 13, 2001), p. 1.
61. "Impact from Crippling of Arun Spreads," *World Gas Intelligence*, Vol. 12, No. 6 (March 22, 2001), p. 3.
62. "Market Insight: Shaky Steps at Arun," *World Gas Intelligence*, Vol. 12, No. 27 (September 12, 2001), p. 6.
63. "Market Insight: Shaky Steps at Arun," *World Gas Intelligence*, Vol. 12, No. 27 (September 12, 2001), p. 6.

64. "Market Insight: Philippine LNG Logic," *World Gas Intelligence*, Vol. 12, No. 36 (November 14, 2001), p. 6.

65. "Malaysian Demand Perkier Than Supply," *World Gas Intelligence*, Vol. 12, No. 24 (August 22, 2001), pp. 2-3.

66. "Indonesia Signs Its First Sale to Malaysia," *World Gas Intelligence*, Vol. 12, No. 7 (April 12, 2001), p. 14.

67. "Yellow Light Only for Thai-Malaysia Pipe," *World Gas Intelligence*, Vol. 12, No. 34 (October 31, 2001), p. 4.

68. "Malaysia Faces Delay in Hub Quest," *World Gas Intelligence*, Vol. 12, No. 10 (May 16, 2001), p. 2.

69. "Malampaya Powers Ahead," *Petroleum Economist* (November 2001), p. 35.

70. "Bangladesh May Allow Gas Exports Afterall," *World Gas Intelligence*, Vol. 12, No. 35 (November 7, 2001), p. 4.

71. "Bangladesh Backfire," *World Gas Intelligence*, Vol. 12, No. 38 (November 7, 2001), p. 5.

72. "East Timor," *Petroleum Intelligence Weekly*, Vol. 40, No. 28 (July 9, 2001), p. 7.

73. "Timor Sea Clouds," *World Gas Intelligence* Vol. 12, No. 22 (August 8, 2001), p. 5.

74. Energy Information Administration, "Country Analysis Brief: Iran," web site www.eia.doe.gov (October 2001).

75. "CFSB Appointed Financial Advisor for Dolphin Project," Dolphin Press Information: Press Releases, web site www.uaedolphin.com (January 7, 2002).

76. Calculated from data in BP p.l.c., *BP Statistical Review of World Energy 2001* (London, UK, June 2001), p. 20, web site www.bp.com.

77. Petroleum Economist, Ltd., *Petroleum Economist World LNG Map, 2001 Edition* (London, UK, March 2001).

78. Petroleum Economist, Ltd., *Petroleum Economist World LNG Map, 2001 Edition* (London, UK, March 2001).

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 2020. Coal continues to dominate many national fuel markets in developing Asia.

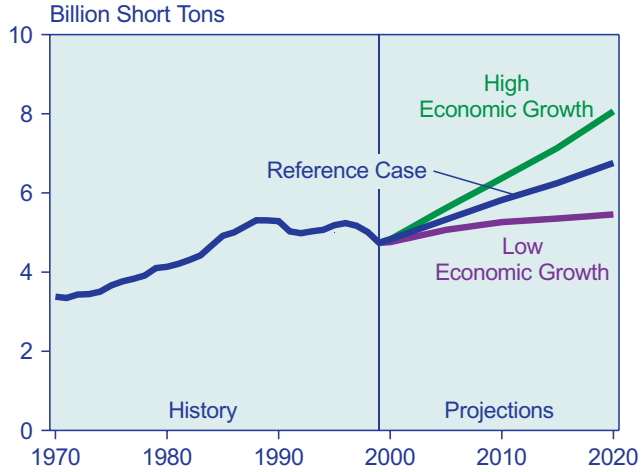
World coal consumption has been in a period of generally slow growth since the late 1980s, a trend that is expected to continue. Although 1999 world consumption, at 4.7 billion short tons,[7] was 15 percent higher than coal use in 1980, it was lower than in any year since 1984 (Figure 53). The *International Energy Outlook 2002* (*IEO2002*) reference case projects some growth in coal use between 1999 and 2020, at an average annual rate of 1.7 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, and developing Asia. In Western Europe, coal consumption declined by 35 percent between 1985 and 1999 (on a Btu basis), displaced in large part by the growing use of natural gas and, in France, nuclear power. Even sharper declines occurred in the countries of Eastern Europe and the former Soviet Union (EE/FSU), where coal use fell by 48 percent between 1985 and 1999 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 1999, coal provided 22 percent of world primary energy consumption, down from 27 percent in 1985. In the *IEO2002* reference case, the coal share of total energy consumption is projected to fall to 20 percent by 2020 (Figure 54).

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 29 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 1999 to 2020 account for 83 percent of the total expected increase in coal use worldwide (on a Btu basis). Still, coal's share of energy use in developing Asia is projected to decline (Figure 55).

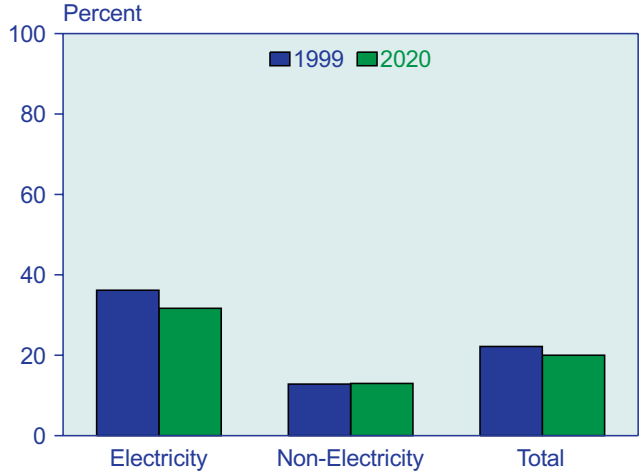
Coal consumption is heavily concentrated in the electricity generation sector, and significant amounts are also used for steel production. Almost 65 percent of the coal

Figure 53. World Coal Consumption, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

Figure 54. Coal Share of World Energy Consumption by Sector, 1999 and 2020



Sources: **1999**: Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **2020:** EIA, World Energy Projection System (2002).

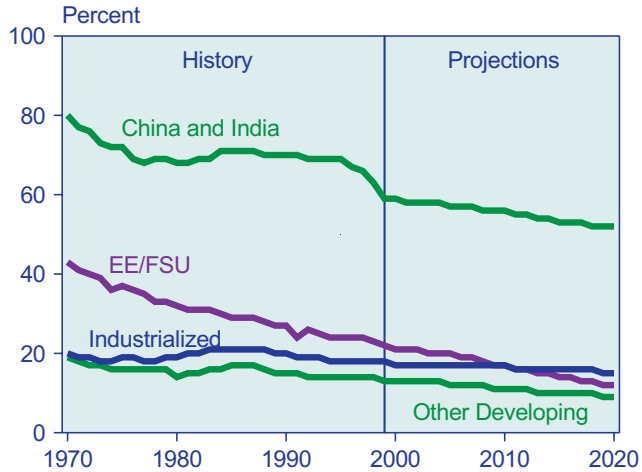
[7]Throughout this chapter, tons refers to short tons (2,000 pounds).

consumed worldwide is used for electricity generation. Power generation accounts for virtually all the projected growth in coal consumption worldwide. 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 *IEO2002* 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 not meet its Kyoto emissions target without reducing annual coal consumption by somewhere between 18 percent and 77 percent (on a Btu basis) by 2010, depending on a number of other assumptions [***1***].

Developments in international coal markets are also important to the coal outlook. World coal trade grew by 55 million tons between 1999 and 2000, increasing to 604 million tons. In 2001, international coal markets were affected by a recovery in ocean shipping rates, higher coal export prices than in 1999 and 2000, and a surge in Chinese coal exports to 95 million tons, representing an increase of nearly 35 million tons over its exports in 2000.

Figure 55. Coal Share of Regional Energy Consumption, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

Highlights of the *IEO2002* projections for coal are as follows:

- World coal consumption is projected to increase by 2.0 billion tons, from 4.7 billion tons in 1999 to 6.8 billion tons in 2020. Alternative assumptions about economic growth rates lead to forecasts of world coal consumption in 2020 ranging from 5.5 to 8.1 billion tons (Figure 53).
- Coal use in developing Asia alone is projected to increase by 1.8 billion tons. China and India together are projected to account for 29 percent of the total increase in energy consumption worldwide between 1999 and 2020 and 83 percent of the world's total projected increase in coal use, on a Btu basis.
- China is projected to add an estimated 100 gigawatts of new coal-fired generating capacity (333 plants of 300 megawatts each) by 2020 and India approximately 65 gigawatts (217 plants of 300 megawatts each).
- The share of coal in world total primary energy consumption is expected to decline from 22 percent in 1999 to 20 percent in 2020. The coal share of energy consumed worldwide for electricity generation is also projected to decline, from 36 percent in 1999 to 32 percent in 2020.
- World coal trade is projected to increase from 604 million tons in 1999 to 776 million tons in 2020, accounting for between 11 and 12 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, and carbon dioxide (CO_2). Recent studies on the health effects of mercury (Hg) have also brought to the forefront concerns about emissions of mercury from coal-fired power plants.

Sulfur dioxide emissions have been linked to acid rain, and many of the industrialized countries have instituted policies or regulations to limit sulfur dioxide emissions. 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 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 [***2***].

At the end of 1999, more than 280 gigawatts of coal-fired capacity around the world—approximately 36 percent of it in the United States—were equipped with FGD or other SO_2 control technologies [***3***]. 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 [***4***].

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 phase out nuclear capacity in full or in large measure. In other countries, it has become difficult to site new capacity because of unfavorable public reaction. The siting of new large hydroelectric dams is also becoming more difficult because of increased environmental scrutiny. In addition, suitable sites for new large hydropower projects in the industrialized countries are limited [***5***].

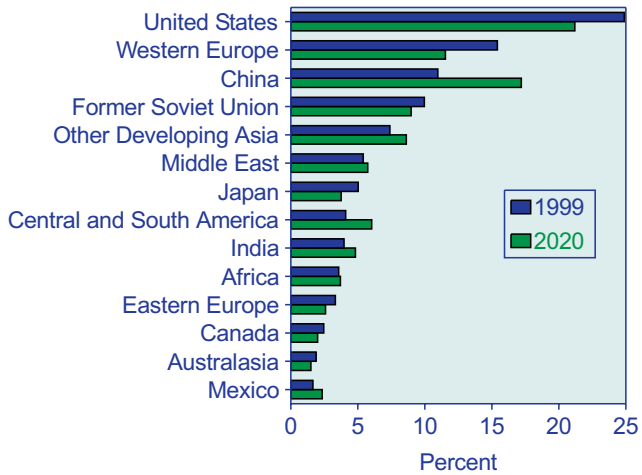
By far the most significant emerging issue for coal is the potential for a binding international agreement to reduce emissions of carbon dioxide and other greenhouse gases. On a Btu basis, the combustion of coal produces more carbon dioxide than the combustion of natural gas or of most petroleum products (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 [***6***].

In 1999, the United States and China were the world's dominant coal consumers and also the two top emitters of carbon dioxide, accounting for 25 percent and 11 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 *IEO2002* forecast to decline to 21 percent by 2020, while China's share is projected to increase to 17 percent (Figure 56). Worldwide, coal is projected to continue as the second largest source of carbon dioxide emissions (after petroleum), accounting for 31 percent of the world total in 2020.

Reserves

Total recoverable reserves of coal around the world are estimated at 1,089 billion tons[8]—enough to last

Figure 56. Regional Shares of World Carbon Emissions, 1999 and 2020



Sources: **1999:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **2020:** EIA, World Energy Projection System (2002).

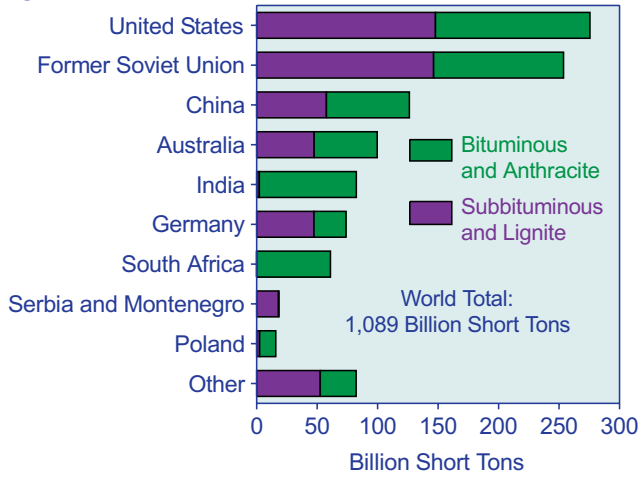
[8]Recoverable reserves are those quantities of coal which geological and engineering information indicates with reasonable certainty can be extracted in the future under existing economic and operating conditions.

approximately 230 years at current consumption levels (Figure 57). 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 1999, these seven regions accounted for 80 percent of total world coal production [***7***].

Quality and geological characteristics of coal deposits are other important parameters for coal reserves. Coal is a much more heterogeneous source of energy than is oil or natural gas, and its quality varies significantly from one region to the next and even within an individual coal seam. For example, Australia, the United States, and Canada are endowed with substantial reserves of premium coals that can be used to manufacture coke. Together, these three countries supplied 84 percent of the coking coal traded worldwide in 2000 (see Table 16 on page 82).

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 1999, lignite accounted for 19 percent of total world coal production (on a tonnage basis) [***8***]. The top three producers were Germany (178 million tons), Russia (99 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 1999. 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 [***9***].

Figure 57. World Recoverable Coal Reserves



Note: Data represent recoverable coal reserves as of January 1, 1999.

Source: Energy Information Administration, *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001), Table 8.2.

Regional Consumption

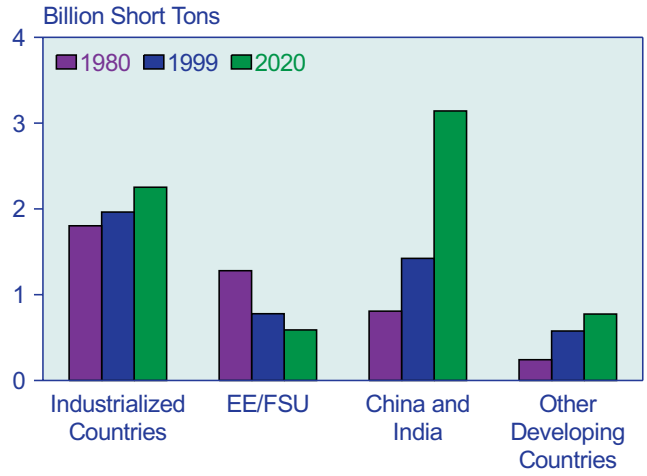
Developing Asia

The countries of developing Asia accounted for 36 percent of the world's coal consumption in 1999. 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 52-percent share of total world coal consumption by 2020.

The large increases in coal consumption projected for China and India are based on an outlook for strong economic growth (7.0 percent per year in China and 5.7 percent per year in India) and the expectation that much of the increased demand for energy will be met by coal, particularly in the industrial and electricity sectors (Figure 58). The *IEO2002* 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, 59 percent of the total increase in coal demand is projected to occur in the non-electricity sectors, for steam and direct heat for industrial applications (primarily in the chemical, cement, and pulp and paper industries) and for the manufacture of coal coke for input to the steelmaking process. In 1999, China was the world's leading producer of both steel and pig iron [***10***].

Figure 58. World Coal Consumption by Region, 1980, 1999, 2020



Sources: **1980 and 1999:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **2020:** EIA, World Energy Projection System (2002).

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 expressed strong interest in developing a coal-to-liquids industry [***11***]. Initial plans call for the construction of several large coal-to-liquids projects over the next 10 years, with work on the first coal liquefaction plant to be initiated in the coal-rich Shanxi Province in late 2001 [***12***]. 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 relatively small, with an annual production capacity of less than 4 million barrels.

In the electricity sector in China, coal use is projected to grow by 2.2 percent a year, from 10.4 quadrillion Btu in 1999 to 16.4 quadrillion Btu in 2020. In comparison, coal consumption by electricity generators in the United States is projected to rise by 1.2 percent annually, from 19.3 quadrillion Btu in 1999 to 25.1 quadrillion Btu in 2020. 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 approximately 300 gigawatts of coal-fired capacity by 2020.[9] At the beginning of 1999, China had 201 gigawatts of coal-fired generating capacity [***13***].

In India, projected growth in coal demand occurs primarily in the electricity sector, which currently accounts for more than two-thirds of India's total coal consumption (see box on page 74). Coal use for electricity generation in India is projected to rise by 2.9 percent per year, from 4.5 quadrillion Btu in 1999 to 8.1 quadrillion Btu in 2020, implying that India will need approximately 125 gigawatts of coal-fired capacity in 2020. At the beginning of 1999, India's total coal-fired generating capacity amounted to 59 gigawatts [***14***].[10]

In the remaining areas of developing Asia, a considerably smaller but significant rise in coal consumption is projected over the forecast period, based on expectations for strong growth in coal-fired electricity generation in South Korea, Taiwan, and the member countries of the Association of Southeast Asian Nations (primarily, Indonesia, Malaysia, the Philippines, Thailand, and Vietnam). In the electricity sector, coal use in the other developing countries of Asia (including South Korea) is projected to rise by 3.4 percent per year, from 2.4 quadrillion Btu in 1999 to 4.9 quadrillion Btu in 2020.

The key motivation for increasing use of coal in other developing Asia is diversity of fuel supply for electricity generation [***15***]. This objective is relatively strong even in countries that have abundant reserves of natural gas, such as Thailand, Malaysia, Indonesia, and the Philippines. In the *IEO2002* forecast, coal's share of fuel consumption for electricity generation in this region is projected to remain fairly constant, decreasing from 28 percent in 1999 to 27 percent by 2020.

Some of the planned additions of coal-fired generating capacity in other developing Asia for 2002 and later include: 6,100 megawatts of new coal-fired capacity for South Korea by 2015; 5,600 megawatts for Malaysia by 2007; and 3,400 megawatts for Thailand by 2007 [***16***]. In addition to planned capacity additions, a number of new coal-fired units have come online in the region between 1999 and 2001, adding a combined total of more than 10,000 megawatts of electric power supply in South Korea (3,700 megawatts), Taiwan (3,720 megawatts), Malaysia (1,000 megawatts), and the Philippines (2,040 megawatts) [***17***]. In Indonesia, several large coal-fired plants also have been completed recently or are near completion (Paiton I, Paiton II and Tanjung Jati-B); however, power purchase agreements with Perusahlaan Umunm Listrik Negara (PLN), Indonesia's state-run utility, are still being negotiated, and power-line transmission capacity to serve the newest generating capacity has not yet been completed [***18***].

Because of environmental concerns and abundant gas reserves, there is considerable uncertainty about additions of planned coal-fired capacity in the region, particularly for countries such as Thailand and Malaysia. A number of individuals and environmental groups argue that a heavy reliance on local supplies of natural gas for electricity generation is a wiser and probably a more economical choice than constructing new coal-fired

[9]Based on the assumption that, on average, coal consumption at China's fleet of coal-fired power plants will rise to a level of 65 trillion Btu per gigawatt by 2020. 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 2002* reference case forecast, U.S. coal-fired power plants are projected to consume an average of 75 trillion Btu of coal per gigawatt of generating capacity in 2020, based on a projected average utilization rate of 84 percent and an average conversion efficiency 33.5 percent.

[10]Based on the assumption that, on average, coal consumption at India's coal-fired power plants will rise to a level of 65 trillion Btu per gigawatt by 2020. See previous footnote for discussion of the factors that affect the amount of coal consumed per unit of generating capacity.

A Profile of Coal in India

Energy consumption in India is dominated by coal. Coal accounts for more than one-half of the energy consumed in the country, and it is expected to remain an important part of the future fuel mix. More than two-thirds of the coal consumed in India is used in the power sector, and coal is also used for steel manufacturing and for such miscellaneous purposes as cooking in rural parts of the country (see figure below).

India has extensive coal reserves, with 80 billion short tons of recoverable anthracite and bituminous coal and 2 billion tons of recoverable lignite and subbituminous coal.[a] Its 82 billion tons of coal reserves account for about 8 percent of the world's total recoverable reserves. Most of the country's coal is subbituminous (non-coking) coal; only 2 to 3 percent is coking coal.[b] As a result, India's steel industry relies on imports of coking coal to meet between 20 and 25 percent of its annual requirements. Indian coal reserves are generally characterized as high in ash content, low in heat value, and relatively low in sulfur content.

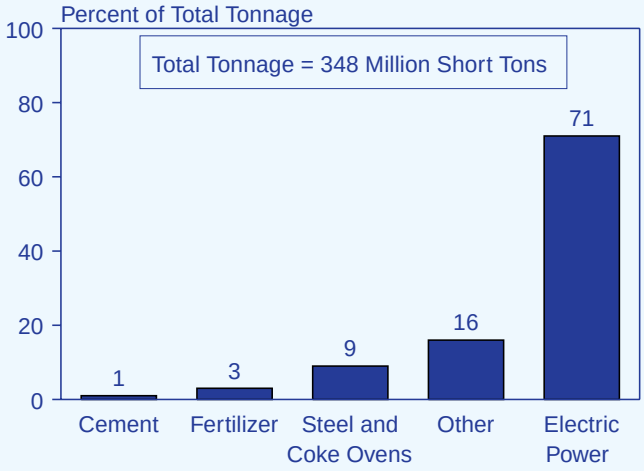
With large coal reserves and heavy use, it is not surprising that India is the third largest producer of coal worldwide. Both surface and underground mining techniques are employed in India. From 1980 to 1997, surface mining increased by a factor of 20, and surface mines currently account for 75 percent of India's total coal output. Underground mining, however, has not developed as rapidly, growing by only 0.7 percent per year from 1980 to 1997, as compared with average growth of 7.6 percent per year for surface mining.[c]

For the most part, coal reserves are located in eastern India in the states of West Bengal, Madhya Pradesh, and Orissa. Coal can also be found in Maharashtra, Uttar Pradesh, and Andhra Pradesh (see map below). The country's lignite reserves are found primarily in the Southern state of Tamil Nadu, as well as Western Gujarat, Rajastan, and Jammu Kashmir.[d]

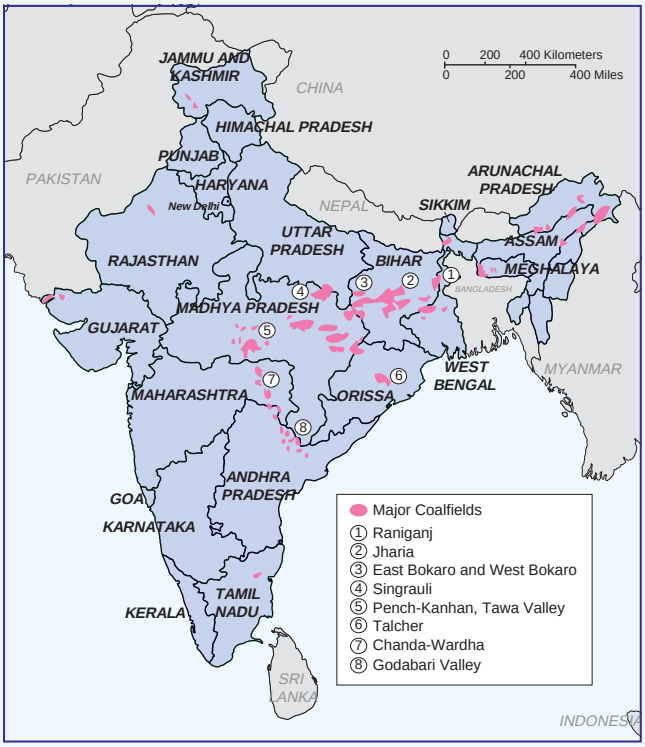
Reserves tend to be located far from the major consuming centers of the central, western, and southern parts of the country. Therefore, transport is a major concern for the Indian coal industry. Some 37 percent of India's non-coking coal is shipped to electric power plants that are located more than 600 miles from the coal mines.[e] Generally, India's coal is shipped by rail, and some is also shipped by road and water. Most commonly, coal

(continued on page 75)

Coal Consumption by End Use Sector, 2000



Source: Tata Energy Research Institute and Fesharaki Associates Consulting and Technical Services, Inc. (FACTS), *Emergence of a New Giant: India's Natural Gas Sector to 2015* (Honolulu, HI, August 2001), p. 2.11; and Energy Information Administration, *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001).



[a]Energy Information Administration, *International Energy Annual 1999*, DOE / EIA-0219(99) (Washington, DC, February 2001), p. 115.
[b]Tata Energy Research Institute, *Tata Energy Data and Directory Yearbook 1999/2000* (New Delhi, India, 1999).
[c]Tata Energy Research Institute, *Tata Energy Data and Directory Yearbook 1999/2000* (New Delhi, India, 1999).
[d]L. Clarke, S. Walker, and O. Montfort, *Coal Prospects in India*, IEAPER / 37 (London, UK: International Energy Agency Coal Research, October 1997), pp. 30-31.
[e]Tata Energy Research Institute, *Tata Energy Data and Directory Yearbook 1999/2000* (New Delhi, India, 1999).

power plants that will rely on imported fuel and produce more pollution than gas-fired plants [**19**].

Industrialized Asia

Among the Asian industrialized countries—Australia, New Zealand, and Japan—Australia is the world's leading coal exporter and Japan is the leading coal importer in the world. In 1999, Australian coal producers shipped 189 million tons of coal to international consumers, and another 141 million tons of Australian coal (both hard coal and lignite) was consumed domestically, primarily for electricity generation. Coal-fired power plants accounted for 78 percent of Australia's total electricity generating needs in 1999 [**20**]. 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 to come online in 2001); Millmerran plant (840 megawatts of capacity to come online in 2002); and Tarong Power plant (450 megawatts scheduled for 2003) [**21**].

Japan, which is the third largest coal user in Asia and the eighth largest globally, imports most all the coal it consumes, much of it originating from Australia [**22**]. 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 [**23**]. 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) [**24**]. Coal is also used heavily in the Japanese power sector, and coal plants currently generate more than 20 percent of the country's electricity supply [**25**]. In 1999, Japanese power producers consumed 65 million tons of coal,

A Profile of Coal in India (Continued)

is shipped by rail to eastern ports, from which it is then shipped by water to southern destinations. There are 11 ports managed by the Port Trust of India, with Haldia, Vishakapatnam, and Paradip the most important eastern ports. Recently, private-sector participation was invited to develop and build additions to existing port facilities.

The coal industry in India is largely held in the public sector. The Ministry of Coal is the public entity that sets "policies and strategies for exploration and development," for the country's coal mines.[f] Coal India, Ltd. (CIL) acts as the holding company and has eight fully-owned subsidiaries. CIL owns 90 percent of total coal production in India and 97 percent of the coalfields. Four major subsidiaries of CIL are Bharat Coking Coal Ltd. (BCCL), Western Coalfields Ltd. (WCL), South Eastern Coalfields Ltd. (SECL), and Northern Coalfields Ltd. (NCL).[g] The coal industry was largely private until the 1970s, when it was nationalized to plan for growing industrial needs and equitable distribution of the country's coal resources. India's coal industry was nationalized in two stages: coking-coal mines in 1971 and other coal mines in 1973.[h] Only coal mines captive to steel mines were not part of the nationalization process.

Eventually, dissatisfaction arose between the coal industry and electric power industry. Disputes concerned the quality and quantity of coal delivered to electric utilities, as well as disputes about payment for the coal. Several other issues also plagued the coal industry, such as the lack of mechanization of certain processes, monopolistic construct of the coal industry, and the lack of State Electricity Board (SEB) funds.[i] To address some of these issues, an agreement was drawn up in 1977. Since then, there has been intermittent acceptance and adherence to that agreement. In 1998, the Indian Council of Power Utilities drafted a new agreement that was circulated to all the utilities as the model agreement. Some SEBs entered into this agreement with CIL, but others have not.

Environmental issues are also increasingly important in India, and they have begun to affect the coal industry. One of the defining characteristics of Indian coal is its high ash content, which increases the amount of pollutants released when it is burned. The ash content can be reduced before use through a benefication or washing process. Washing plants for coking coal exist, but many are old and low in unit capacity. In an attempt to lessen the pollutants emitted by burning coal, the Ministry of Environment and Forestry decreed that as of June 1, 2001, all coal supplied to power plants located further than 620 miles from the coal fields, or those located in critically polluted and sensitive urban areas, must have an ash content of no more than 34 percent.[j]

[f]India Ministry of Coal, "Aboust Us," web site http://coal.nic.in/vscoal/sub1.html (not dated).

[g]M. Kulshreshtha and J.K. Parikh, "A Study of Productivity in the Indian Coal Sector," *Energy Policy*, Vol. 29, No. 9 (July 2001) pp. 701-713.

[h]"Making Arrangements To Supply Coal," web site www.terrin.org/energy/coal.htm (April 2001).

[i]"Making Arrangements To Supply Coal," web site www.terrin.org/energy/coal.htm (April 2001).

[j]Mining India, "Clamp on Use of Raw Coal in Thermal Power Plants," web site www.miningindia.com/writeups/798/24.htm (not dated).

representing 42 percent of the country's total coal consumption [**26**]. Japanese power companies plan to construct an additional 16 gigawatts of new coal-fired generating capacity between 2001 and 2010 [**27**].

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 decreased by 39 percent over the past 9 years, from 894 million tons in 1990 to 546 million tons in 1999. The decline was smaller on a Btu basis, at 32 percent, reflecting the fact that much of it resulted from reduced consumption of low-Btu lignite in Germany.

Over the forecast period, Western European coal consumption is projected to decline by an additional 23 percent (on a Btu basis), reflecting a slower rate of decline than was experienced during the previous decade. Factors contributing to further cutbacks in coal consumption include further 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.

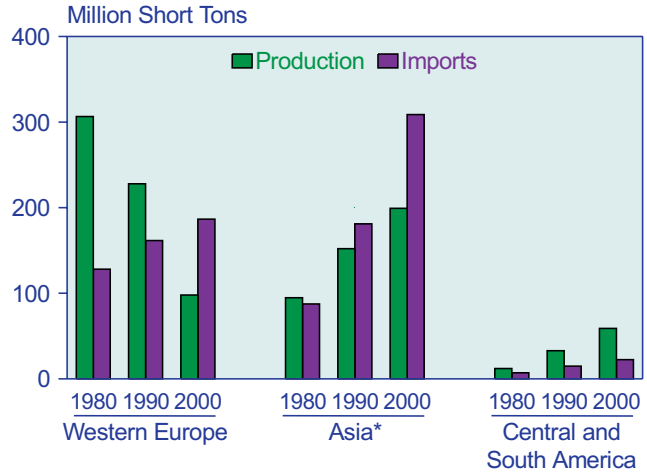
The current set of guidelines for state aid to the European coal industry (Commission Decision No. 3632/93/ECSC of December 28, 1993) is set to expire on July 23, 2002, coinciding with the expiration date of the 50-year European Coal and Steel Community Treaty of 1951. In light of these pending expiration dates, 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 [**28**]. 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[11] 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 59). Following the closure of the last remaining coal mines in Belgium in 1992 and Portugal in 1994, only four member States of the European Union (the United Kingdom, Germany, Spain, and France) continue to produce hard coal [**29**], 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 [**30**].

Hard coal production in the United Kingdom decreased from 104 million tons in 1990 to 40 million tons in 1999, a decline of 64 million tons [**31**]. During the same period, coal consumption fell by 53 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 [**32**]. 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

Figure 59. Production and Imports of Hard Coal by Region, 1980, 1990, and 2000



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

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

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

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

were introduced, primarily aimed at getting generators to price their electricity more competitively. 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 [***33***]. Although the impact of the NETA measures on Britain's coal-fired generation is not yet known, they are generally seen as an improvement over the country's previous wholesale electricity market (the Electricity Pool). The lifting of the moratorium on the construction of new gas plants, however, opened the door for the planned construction of six new combined-cycle gas plants (representing 4.8 gigawatts of capacity), whose output will likely compete with generation from the country's existing coal-fired plants [***34***].

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 increase in average labor productivity from 1,190 tons per miner-year in 1990 to 3,200 tons per miner-year in 1999 [***35***]. 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 [***36***]. In fact, following several years of sharp declines in international coal prices in 1998 and 1999, the UK government reinstated coal production subsidies for 2000 through 2002 in an effort to protect the country's remaining coal operations (Table 15) [***37***].

In Germany, Spain, and France, subsidies continue to support the domestic production of hard coal,[12] even though there is no hope that their production will ever be competitive with imports. For 2000, the European Commission authorized coal industry subsidies of $4,245 million in Germany, $1,035 million in Spain, and $933 million in France. In each of the three countries, the average subsidy per ton of coal produced exceeds the average value of imported coal (Table 15), 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 48 million tons in 1999 [***38***]. In March 1997, the federal government, the mining industry, and the unions reached an agreement on the future structure of subsidies to the German hard coal industry. At that time, the agreement called for the closure of 8 to 9 of Germany's 19 operating hard coal mines, leading to an estimated decline in production to 33 million tons by 2005 [***39***]. The closure of three coal mines in 2000 (with a combined production capacity of approximately 8.3 million tons) left Germany with 12 operating hard coal mines at the end of the year [***40***].

Between 1990 and 1999, German lignite production declined by 242 million tons, primarily as a result of massive substitution of natural gas for both lignite and lignite-based "town gas"[13] in the eastern states following reunification in 1990 [***41***]. The collapse of industrial output in the eastern states during this period also was a contributing factor. In the *IEO2002* reference case, Germany's coal consumption is projected to continue falling, although not as dramatically as in recent years. By 2020, coal use in Germany is projected to be 219 million tons, a drop of 39 million tons from the 1999 level of 258 million tons.

In Spain, hard coal production declined from 22 million tons in 1990 to 17 million tons in 1999 [***42***]. Spain has adopted a restructuring plan for 1998 through 2005 that provides for a gradual decline in production to 12 million tons [***43***]. In addition to hard coal, two lignite mines in Spain, which produced 10 million tons in 1999, are earmarked for closure within the next 3 to 4 years [***44***].

Table 15. Western European Coal Industry Subsidies, Production, and Import Prices, 2000

Country	Coal Industry Subsidies (Million 2000 U.S. Dollars)	Hard Coal Production (Million Tons)	Average Subsidy per Ton of Coal Produced (2000 U.S. Dollars)	Average Price per Ton of Coal Imported (2000 U.S. Dollars)
Germany	4,245	40.4	105	32
Spain	1,035	16.4	63	32
France	933	4.9	192	36
United Kingdom . .	132	35.3	4	38

Sources: **Coal Production Subsidies:** Commission of the European Communities, *Proposal for a Council Regulation on State Aid to the Coal Industry* (Brussels, Belgium, July 25, 2001), p. 28, web site www.europa.eu.int; and U.S. Federal Reserve Bank, "Foreign Exchange Rates (Annual)," web site www.bogfrb.fed.us (January 9, 2001). **Production:** Energy Information Administration, Office of Energy Markets and End Use, International Statistics Database. **Average Price of Coal Imports:** International Energy Agency, *Coal Information 2001* (Paris, France, September 2001).

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

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

Currently, the two generating plants that burn the lignite produced by the mines also rely partly on imports of subbitumnous 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 6 million tons in 1999 [***45***]. 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 [***46***]. The coal industry 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 [***47***]. In 1999, 51 percent of Denmark's electricity was supplied by coal-fired plants [***48***]. Coal consumption in Italy is projected to remain relatively flat in the *IEO2002* forecast.

Partly 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 [***49***].

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 597 million tons since 1990, to 778 million tons in 1999. 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 *IEO2002* reference case, coal's share of total EE/FSU energy consumption is projected to decline from 22 percent in 1999 to 12 percent in 2020, and the natural gas share is projected to increase from 45 percent in 1999 to 50 percent in 2020.

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 1999, coal production declined by 151 million tons (37 percent) in Russia, by 91 million tons (51 percent) in Ukraine, and by 64 million tons (56 percent) in Kazakhstan [***50***]. While both Kazakhstan and Russia have shown considerable progress in terms of closing uneconomical mining operations and in selling government-run mining operations to the private sector, Ukraine has made considerably less progress in its restructuring efforts. In Kazakhstan, many of the high-cost underground coal mines have been closed, and its more competitive surface mines have been purchased and are now operated by international energy companies [***51***]. 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 is expected to increase to 90 percent by the end of 2002 [***52***].

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 at rejuvenating the industry. Key problems that continue to plague the Ukrainian coal industry are : (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 [***53***].

The World Bank has focused its efforts in Ukraine on trying to convince the government that it needs to close additional unprofitable mines [***54***]. 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 [***55***]. On the other hand, 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, the existence of 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).

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 [**56**]. The *IEO2002* outlook for FSU coal consumption, however, indicates only slight positive growth between 1999 and 2005 with a declining trend thereafter. 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 [**57**]. In 1999, coal consumption in Poland totaled 164 million tons, 45 percent of Eastern Europe's total coal consumption for the year [**58**]. Poland's hard coal industry produced 123 million tons in 1999, and lignite producers contributed an additional 67 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 less than 6 million tons in 1999 [**59**].

In 2001 Poland's hard coal industry operated at a slight loss, but it is expected to operate in the black in 2002 [**60**]. Over the past several years, a number of coal industry restructuring plans have been put forth for the purpose of transforming Poland's hard coal industry to a position of positive earnings, eliminating the need for government subsidies. The most recent plan was announced by Poland's Ministry of the Economy in March 1998. It called for the closure of 24 of the country's 50 unprofitable mines over the next 4 years, reducing the total number of mines in Poland from 65 in 1998 to 41 by 2002. In addition, the restructuring plan aims to reduce the number of miners by one-half, from 245,000 in 1998 to 128,000 by 2002 [**61**]. 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 2020. 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 [**62**].

North America

Coal use in North America is dominated by U.S. consumption. In 1999, the United States consumed 1,045 million tons, accounting for 93 percent of the regional total. By 2020 U.S. consumption is projected to rise to 1,365 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 1999 and is projected to provide 46 percent in 2020 [**63**]. 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 31 gigawatts of new coal-fired power plants by 2020. Over the forecast period, the average utilization rate of coal-fired generating capacity is projected to rise from 68 percent in 1999 to 84 percent by 2020.

In Canada, coal consumption accounted for approximately 12 percent of total energy consumption in 1999 and is projected to more or less maintain that share over the forecast period. In the near term, the restart of six of Canada's nuclear generating units (four at the 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, while increased demand for electricity in western Canada is expected to result in the need for some additional coal-fired generation there [**64**]. Fording, Inc., Canada's lead exporter of metallurgical grade coal, is currently exploring the possibility of building a new 1,000-megawatt coal-fired generation plant in the Province of Alberta, approximately 110 miles southeast of Calgary [**65**].

Mexico consumed 13 million tons of coal in 1999. 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 [**66**]. In addition, CFE is currently in the process of switching 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. During 2001, CFE awarded a contract for 3.3 million tons of Chinese coal for delivery over a 6-month period ending April 2002 [**67**]. 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 [**68**].

While natural gas is expected to fuel most new generating capacity to be built in Mexico over the *IEO2002* 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 [**69**]. 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 [**70**]. 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 [**71**].

Africa

Africa's coal production and consumption are concentrated heavily in South Africa. In 1999, South Africa produced 248 million tons of coal, 70 percent of which went to domestic markets and the remainder to exports [***72***]. 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. 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 [***73***].

For Africa as a whole, coal consumption is projected to increase by 35 million tons between 1999 and 2020, primarily to meet increased demand for electricity, which is projected to increase at a rate of 3.6 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 its power sector [***74***]. 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 [***75***]. 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 [***76***].

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 or 1,356 megawatts, this 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 [***77***].

Central and South America

Historically, coal has not been a major source of energy in Central and South America. In 1999, coal accounted for about 5 percent of the region's total energy consumption, and in years past its share has never exceeded 6 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 eighth largest steel industry worldwide in 1999, accounted for more than 66 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 [***78***]. 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 [***79***].

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 [***80***]. 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 [***81***].

In Puerto Rico, the construction of a new coal-fired power plant is underway as part of a long-range plan to reduce the country's dependence on oil for electricity generation [***82***]. The 454-megawatt circulating fluidized bed (CFB) plant will require approximately 1.5 million tons of imported coal annually [***83***].

Middle East

Turkey accounts for almost 90 percent of the coal consumed in the Middle East. In 1999, Turkish coal consumption reached 84 million tons, most of it low-Btu, locally produced lignite (approximately 6.8 million Btu per ton) [***84***]. Over the forecast period, coal consumption (both lignite and hard coal) is projected to increase by 20 million tons, primarily to fuel additional coal-fired generating capacity. Two 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 [***85***]. 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 10 million tons of coal in 1999, 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 attributable to the completion of two new 575-megawatt coal-fired units at Israel Electric Corporation's Rutenberg plant in 2000 and 2001 [***86***]. Based on plans to complete an additional 1,200 megawatts of coal-fired generating capacity at the Rutenberg site in 2007 and 2008, additional growth in Israel's coal consumption is projected [***87***]. Some environmental groups and government officials in Israel are opposed to the recent go-ahead given to Israel Electric to construct additional coal plants, arguing that sufficient supplies of natural gas from both local and Egyptian sources will be available for electricity generation later in the decade.

Trade

Overview

The amount of coal traded in international markets is small in comparison with total world consumption. In 2000, world imports of coal amounted to 604 million tons (Figure 60 and Table 16), representing 13 percent of total consumption. By 2020, coal imports are projected to rise to 776 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.

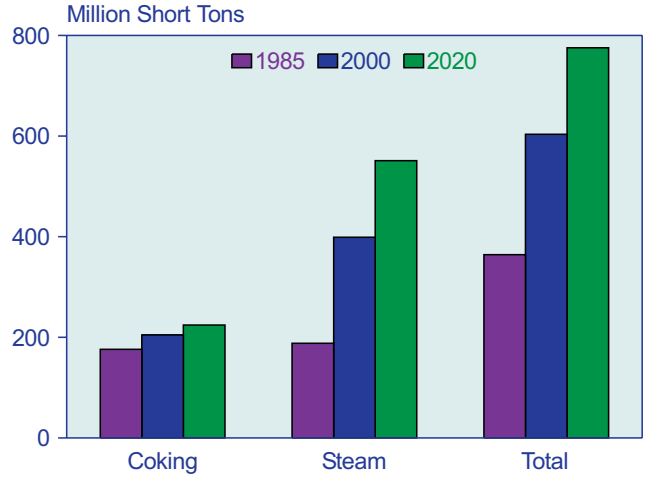
In recent years, international coal trade has been characterized by relatively stable demand for coal imports in Western Europe and expanding demand in Asia (Figure 59). Rising production costs in the indigenous coal industries in Western Europe, combined with continuing pressure to reduce industry subsidies, have led to substantial declines in production there, creating the potential for significant increases in coal imports; however, 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 2000 and 2001, international coal markets have undergone some significant changes on both the supply and demand side. In 2000, international coal markets were affected by several factors, including higher ocean freight rates, strong growth in coal import demand, a recovery in coal export prices (FOB port of exit) late in the year, and a substantial increase in coal exports from China. On the transport side, ocean freight rates rose substantially in 2000, with rates for much of the year typically double those seen in 1999. The primary impacts of the higher rates were a shift in world coal trade patterns to shorter shipping routes for the year (for example, South Korea increased its take of coal from China in 2000, reducing its imports from more distant sources, such as Australia and South Africa [***88***]) and a higher delivered cost of coal imports. On the demand side, world coal trade rose substantially, increasing from 548 million tons in 1999 to 604 million tons in 2000.

The year 2001 was marked by continuing growth in coal import demand, further recovery in coal export prices from historical lows reached in 1999 and early 2000, a continuation of favorable exchange rates vis-a-vis the U.S. dollar for several key exporting countries [***89***],[14] and a continuing surge in coal exports from China. One key difference between 2000 and 2001 was a return to much lower coal transportation rates in 2001, increasing the competitiveness of longer range shipments such as exports of Australian coal to Western Europe [***90***].

Between 1998 and 2000 coal exports from China expanded by 67 percent, from 36 million tons in 1998 to 41 million tons in 1999 and 60 million tons in 2000. Preliminary data indicate that China exported 95 million tons of coal during 2001 [***91***], making it the second leading coal export country in the world, ahead of South Africa and Indonesia. The United States, which was the

Figure 60. World Coal Trade, 1985, 2000, and 2020



Sources: **1985:** Energy Information Administration (EIA), *Annual Prospects for World Coal Trade 1987*, DOE/EIA-0363(87) (Washington, DC, May 1987). **2000:** International Energy Agency, *Coal Information 2001* (Paris, France, September 2001); Energy Information Administration, *Quarterly Coal Report, October-December 2000*, DOE/EIA-0121(2000/4Q) (Washington, DC, May 2001). **2020:** Energy Information Administration, National Energy Modeling System run IEO2002.D011402A (January 2002).

[14]The exchange rate for the Australian dollar was US$0.51 in December 2001, 36 percent below its recent historical peak of US$0.80 in May 1996. The exchange rate for the South African Rand was US$0.09 in December 2001, 67 percent below its recent historical peak of US$0.27 in January 1996. Between August 1998 and November 2001, the Russian ruble lost 77 percent of its value compared with the U.S. dollar.

Table 16. World Coal Flows by Importing and Exporting Regions, Reference Case, 2000, 2010, and 2020
(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]
	2000											
Australia	13.8	83.2	2.3	**96.7**	25.7	76.2	6.6	**109.1**	39.5	159.4	8.9	**205.8**
United States	5.8	4.3	15.4	**25.6**	21.6	2.3	8.9	**32.8**	27.4	6.6	24.3	**58.4**
South Africa	55.6	14.4	1.3	**74.3**	0.4	0.3	1.0	**2.8**	56.0	14.7	2.3	**77.1**
Former Soviet Union	18.4	6.0	0.1	**23.3**	3.1	3.7	0.0	**8.0**	21.5	9.7	0.1	**31.3**
Poland	15.7	0.0	0.0	**14.6**	3.3	0.0	0.1	**3.0**	19.0	0.0	0.1	**17.6**
Canada	0.3	3.3	0.7	**5.1**	8.2	19.3	3.6	**32.8**	8.5	22.6	4.3	**37.9**
China	3.2	53.8	0.2	**53.0**	0.3	7.1	0.0	**7.4**	3.5	60.9	0.2	**60.4**
South America[e]	30.4	0.0	15.0	**46.4**	0.4	0.1	0.1	**0.7**	30.8	0.1	15.1	**47.1**
Indonesia[f]	4.5	46.5	2.4	**59.8**	0.5	10.6	0.0	**11.2**	5.0	57.1	2.4	**71.0**
Total	**147.7**	**211.5**	**37.5**	**398.8**	**63.5**	**119.6**	**20.4**	**204.7**	**211.2**	**331.1**	**57.9**	**603.5**
	2010											
Australia	10.0	108.2	0.7	**118.8**	35.6	85.5	8.0	**129.1**	45.6	193.7	8.7	**247.9**
United States	3.1	6.7	8.6	**18.4**	13.4	1.3	15.5	**30.2**	16.5	8.0	24.2	**48.7**
South Africa	70.5	8.2	4.4	**83.0**	1.1	0.5	0.0	**1.7**	71.6	8.7	4.4	**84.7**
Former Soviet Union	19.6	6.1	0.0	**25.6**	3.0	4.3	0.0	**7.3**	22.5	10.4	0.0	**32.9**
Poland	8.0	0.0	0.0	**8.0**	1.1	0.0	0.0	**1.1**	9.1	0.0	0.0	**9.1**
Canada	5.0	0.0	0.0	**5.0**	6.9	13.8	3.3	**24.0**	11.9	13.8	3.3	**29.0**
China	0.0	113.5	0.0	**113.5**	0.0	12.4	0.0	**12.4**	0.0	125.9	0.0	**125.9**
South America[e]	36.4	0.0	34.8	**71.2**	0.0	0.0	0.0	**0.0**	36.4	0.0	34.8	**71.2**
Indonesia[f]	7.6	65.9	0.0	**73.5**	0.5	9.1	0.0	**9.6**	8.1	75.0	0.0	**83.1**
Total	**160.3**	**308.5**	**48.4**	**517.2**	**61.6**	**126.9**	**26.8**	**215.3**	**221.9**	**435.5**	**75.2**	**732.6**
	2020											
Australia	9.3	112.7	0.7	**122.7**	35.8	89.7	12.4	**137.9**	45.1	202.4	13.1	**260.6**
United States	1.9	7.5	7.2	**16.6**	12.1	1.4	18.1	**31.7**	14.1	8.9	25.3	**48.3**
South Africa	67.7	17.0	4.3	**89.0**	0.9	0.6	0.0	**1.5**	68.6	17.6	4.3	**90.5**
Former Soviet Union	16.1	7.2	0.0	**23.3**	3.0	4.7	0.0	**7.7**	19.1	11.9	0.0	**31.0**
Poland	5.5	0.0	0.0	**5.5**	1.1	0.0	0.0	**1.1**	6.6	0.0	0.0	**6.6**
Canada	2.9	0.0	0.0	**2.9**	6.8	14.0	1.7	**22.5**	9.7	14.0	1.7	**25.4**
China	0.0	121.3	0.0	**121.3**	0.0	12.4	0.0	**12.4**	0.0	133.6	0.0	**133.6**
South America[e]	50.0	0.0	36.1	**86.1**	0.0	0.0	0.0	**0.0**	50.0	0.0	36.1	**86.1**
Indonesia[f]	0.0	83.8	0.0	**83.8**	0.4	9.2	0.0	**9.6**	0.4	93.0	0.0	**93.4**
Total	**153.4**	**349.4**	**48.3**	**551.1**	**60.2**	**132.1**	**32.2**	**224.4**	**213.6**	**481.4**	**80.5**	**775.5**

[a]Reported data for 2000 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 2000, total world coal flows include a balancing item used by the International Energy Agency to reconcile discrepancies between reported exports and imports. The 2000 balancing items by coal type were 2.1 million tons (steam coal), 1.2 million tons (coking coal), and 3.3 million tons (total).

[d]Includes 14.4 million tons of coal for pulverized coal injection at blast furnaces shipped to Japanese steelmakers in 2000.

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

[f]In 2000, coal exports from Indonesia include shipments from other countries not modeled for the forecast period. The 2000 non-Indonesian exports by coal type were 6.2 million tons (steam coal), 1.5 million tons (coking coal), and 7.7 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: **2000:** International Energy Agency, *Coal Information 2001* (Paris, France, September 2001); Energy Information Administration, *Quarterly Coal Report, October-December 2000*, DOE/EIA-0121(2000/4Q) (Washington, DC, May 2001). **Projections:** Energy Information Administration, National Energy Modeling System run IEO2002.D011402A (January 2002).

second largest coal exporter 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 [***92***]. China's 10th Five-Year Plan envisions that coal exports will exceed 110 million tons by 2005 [***93***].

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 2020, slightly less than its 2000 share of 27 percent [***94***]. In 2000, Japan produced just over 3 million tons of coal for domestic consumption and imported 160 million tons. The closure of Japan's Miike mine in March 1997 left the country with two remaining underground coal mines and several small surface mines [***95***]. The last two underground mines, Ikeshima and Taiheiyo, were closed in late 2001 and early 2002, respectfully, leaving virtually all of Japan's coal requirements to be met by imports [***96***].

As the leading importer of coal, Japan has been influential in the international coal market. Historically, contract negotiations between Japan's steel mills and coking coal suppliers in Australia and Canada established a benchmark price for coal that was used later in the year as the basis for setting contract prices for steam coal used at Japanese utilities [***97***]. 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 [***98***].

Similar changes have occurred in the annual negotiation process between Japanese electric utilities and Australian steam coal suppliers, with a tiered pricing structure replacing a single benchmark price. Through 2000, the new pricing system was characterized by a relatively small portion of Australia's coal shipments to Japanese utilities being priced at or slightly below a negotiated "reference" price, with the remaining tonnage priced considerably lower [***99***]. The more recent environment of high spot prices for coal in 2001, however, has made the current reference pricing system for coal considerably less attractive to Japanese electricity producers, as they are essentially having to pay prices that are higher than the negotiated "reference price" for much of their purchased tonnage. As a result, Japan's Chubu Electric Power Company has been exploring alternative pricing schemes—reportedly trying to find the best way to minimize the average annual price they pay for coal [***100***].

In essence, liberalization of the Japanese electricity market is placing increased cost-cutting pressure on utilities, making them less concerned about long-term supply and much more focused on prices. What seems to be occurring in the Asian coal markets is a shift away from contract purchases to the spot market. The shift to more competitive coal markets in Asia implies that coal producers in Australia and other exporting countries will be under increased pressure to reduce mining costs in order to maintain current rates of return. It also means that less competitive suppliers, such as the United States, will find it difficult to increase or maintain coal export sales to the region.

China and India, which import relatively small quantities of coal at present, are expected to account for 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 (1.6 billion tons) in coal demand. In addition, coal imports by Malaysia, the Philippines, and Thailand are also projected to rise substantially over the forecast period, primarily to satisfy demand at new coal-fired power plants. Diversification of fuel supply for electricity generation is the key factor underlying plans for additional coal-fired generating capacity in these countries.

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 countries such as Japan began using some of Australia's semi-soft or weak coking coals in their coke oven blends. As a result, imports of hard coking coals from other countries, including the United States, were displaced. Australia's share of total world coal trade, which increased from 17 percent in 1980 to 34 percent in 2000, is projected to remain near that level over the forecast period [***101***]. Australia should continue as the major exporter to Asia, but its share of the region's total coal import demand is projected to decline from 48 percent in 2000 to 42 percent by 2020.

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 [***102***]. 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 realtively short transport distances from China's coal-exporting ports to Asia's major coal-importing countries, ensuring low shipping costs [***103***]. Over the forecast period, China is expected to capture an increasing share of the region's overall coal import market.

Europe, Middle East, and Africa

Coal imports to Europe, the Middle East, and Africa taken as a whole are projected to remain relatively constant over the forecast period (Figure 61). 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.

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 2000, the leading suppliers of imported coal to Europe were South Africa (27 percent), Australia (19 percent), South America (15 percent), and the United States (13 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.

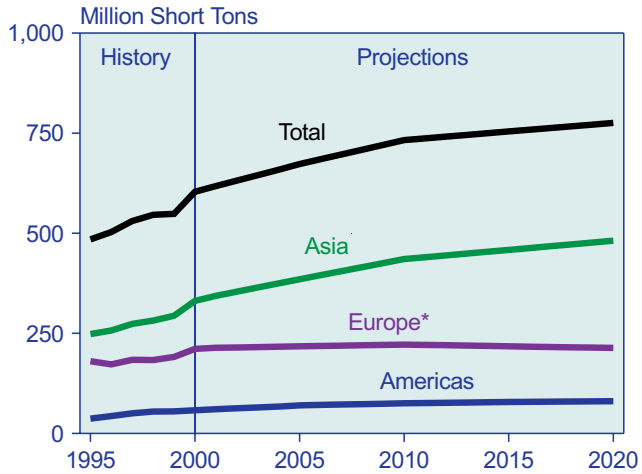
Despite expected gains in South America's foothold in Europe, South Africa is projected to maintain its position as the leading supplier of coal to Europe. Recently announced plans call for an 11-million-ton expansion in South Africa's Richards Bay Coal Terminal by the end of 2003, increasing the facility's annual coal export capacity to 90 million tons [***104***].

The Americas

Compared with European and Asian coal markets, imports of coal to North and South America are relatively small, amounting to only 58 million tons in 2000 (Table 16). Canada imported 33 percent of the 2000 total, followed by Brazil (26 percent) and the United States (22 percent) [***105***]. Most (81 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 [***106***].

Over the *IEO2002* forecast period, coal imports to the Americas are projected to increase by 23 million tons, with most of the additional tonnage going to the United States, Mexico, and Brazil. Coal imports to the United States are projected to increase from 13 million tons in 2000 to 20 million tons by 2020 [***107***]. Coal-fired power plants 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.

Figure 61. Coal Imports by Major Importing Region, 1995-2020



*Coal imports to Europe include imports to the Middle East and Africa.

Note: Data exclude non-seaborne shipments of coal to Europe and Asia.

Sources: **1995-2000:** International Energy Agency, *Coal Information 2001* (Paris, France, September 2001); Energy Information Administration, *Quarterly Coal Report, October-December 2000*, DOE/EIA-0121(2000/4Q) (Washington, DC, May 2001), and previous issues. **Projections:** Energy Information Administration, National Energy Modeling System run IEO2002.D011402A (January 2002).

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, displacing 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 1999 and 2001 [***108***]. 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 [***109***].

Coking Coal

Historically, coking coal has dominated world coal trade, but its share has steadily declined, from 55 percent in 1980 to 34 percent in 1999 [***110***]. In the forecast, its share of world coal trade continues to shrink, to 29 percent by 2020. 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 [***111***].[15] In 1999, the direct use of pulverized coal at blast furnaces accounted for 17 percent and 19 percent of the coal consumed for steelmaking in the European Union and Japan, respectively [***112***].

References

1. Energy Information Administration, *Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity*, SR/OIAF/98-03 (Washington, DC, October 1998), Table B1.
2. East-West Center, *Interfuel Competition in the Power Sector: Fuel Price Comparisons in the Asia-Pacific Region*. Report to the Energy Information Administration (May 2000).
3. IEA Coal Research, *Developments in FGD*, CCC/29 (London, UK, March 2000), pp. 12 and 74.
4. Standard & Poor's, *Asia/Pacific World Energy Global Energy Market Research & Analysis 2001* (Lexington, MA, 2001), p. 72, Table 28.
5. Directorate-General XVII—Energy, European Commission, *Energy in Europe: European Union Energy Outlook to 2020* (Brussels, Belgium, November 1999), pp. 44-45.
6. Energy Information Administration, *Emissions of Greenhouse Gases in the United States 2000*, DOE/EIA-0573(2000) (Washington, DC, November 2001), Table B1.
7. Energy Information Administration, *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001), Table 2.5.
8. Energy Information Administration, *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001), Tables 2.5 and 5.4.
9. International Energy Agency, *Coal Information 2001* (Paris, France, September 2001), pp. II.21-II.23.
10. Web site www.worldsteel.org.
11. Energy Information Administration, "Country Analysis Brief: China," web site www.eia.doe.gov (April 2001).
12. "China Boosts 'Coal-For-Oil' To Curb Pollution, Oil Shortage," *World News Connection* (March 1, 2001).
13. Standard & Poor's, *Asia/Pacific World Energy Global Energy Market Research & Analysis 2001* (Lexington, MA, 2001), p. 72, Table 28.
14. Standard & Poor's, *Asia/Pacific World Energy Global Energy Market Research & Analysis 2001* (Lexington, MA, 2001), p. 101, Table 28.
15. "Asia Won't Yet Kick the Coal Habit," *Petroleum Intelligence Weekly* (July 9, 2001), p. 4; S. Johari, "Tenaga Seeks To Delay Two Coal-Fired Plant Projects," *Business Times (Malaysia)* (July 4, 2001), p. 4; Z. Abdullah, "TNB To Rely More on Coal," *The New Straits Times* (August 25, 2001), Section 2, p. 21; Y. Praiwan, "Plants Essential To Avoid Serious Fall in Reserves," *Bangkok Post* (September 28, 2001).
16. "Korea: 5th Long-Term Power Development Plan," *International Market Insight Reports* (February 10, 2001); "Malaysia To Raise Coal Generation Despite Gas Deposits, Says TNB Head," *Coal Week International* (January 8, 2001), p. 8; D. A. Bakar, "TNB Gives Approval for Relocation of Coal-Fired Plant,"

[15] 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.

The New Straits Times (August 25, 2001), Section 2, p. 1; "Coal Imports To Grow as Thailand Brings on New Power Plants," *Coal Week International* (March 12, 2001), p. 5; "BLCP To Begin Work on Thai Coal Plant Next Year," *Coal Week International* (August 20, 2001), p. 3; Y. Praiwan, "Plants Essential To Avoid Serious Fall in Reserves," *Bangkok Post* (September 28, 2001).

17. "Korea: 5th Long-Term Power Development Plan," *International Market Insight Reports* (February 10, 2001); "Formosa Plastic Says Tender Filled 9 Million MT Coal Needed for 2001," *Coal Week International* (January 22, 2001), p. 8; "Taiwan's Ho-Ping Power To Start Test Runs in 1st Unit Wednesday," *Dow Jones Newswires* (July 31, 2001).
18. "IPP Jawa Power Seeks $0.05 / kWh Rate From Indonesia's PLN," *Dow Jones Newswires* (September 25, 2001); D.J. Smith, "The Re-Awakening of the Asian Tiger," *Power Engineering* (August 1, 2000), pp. 46-49; J. McBeth, "Indonesia," *Far Eastern Economic Review* (March 29, 2001), p. 14.
19. "Asia Won't Yet Kick the Coal Habit," *Petroleum Intelligence Weekly* (July 9, 2001), p. 4; N.B. Srinivasan, "Gas Versus Coal: It's No Contest," *The Bangkok Post* (October 25, 2001), p. 1; "Thai New Power Development Plan To Focus on Natural Gas," *Dow Jones Newswires* (March 15, 2001).
20. International Energy Agency, *Coal Information 2001* (Paris, France, September 2001), Table 3.3a.
21. "Queensland Premier Opens First of Three New Coal-Fired Stations," *Coal Week International* (July 9, 2001), p. 3.
22. Energy Information Administration, *International Energy Annual 1999*, DOE / EIA-0219(99) (Washington, DC, February 2001), Table 1.4.
23. "Japanese Coal Mine To Cease Operation," *International Coal Trade* (October 8, 2001) 1351, p. 17; "Ikeshima Coal Mine Closed After 42 Years in Business," *Kyoda News* (November 28, 2001); K. Hall, "Ending Era, Japan's Last Coal Mine Shuts Down," Associated Press Newswires (January 30, 2002).
24. Web site www.worldsteel.org; and International Energy Agency, *Coal Information 2001* (Paris, France, September 2001), Tables 3.9 and 3.10.
25. International Energy Agency, *Coal Information 2001* (Paris, France, September 2001), Table 3.3a.
26. International Energy Agency, *Coal Information 2001* (Paris, France, September 2001), p. I.94.
27. H. Tagawa, Manager, Coal Fuel Department, Tokyo Electric Power Company, "Coal-Fired Power Generation in Japan and Expectations Toward U.S. Western Coal." Paper presented at the Western Coal Council's 2001 Spring Pacific Coal Forum (Park City, UT, June 4-6, 2001).
28. Commission of the European Communities, *Proposal for a Council Regulation on State Aid to the Coal Industry* (Brussels, Belgium, July 25, 2001), web site www.europa.eu.int.
29. Directorate-General XVII—Energy, European Commission, *The Market for Solid Fuels in the Community in 1996 and the Outlook for 1997* (Brussels, Belgium, June 6, 1997), web site www.europa.eu.int.
30. Commission of the European Communities, *Proposal for a Council Regulation on State Aid to the Coal Industry* (Brussels, Belgium, July 25, 2001), p. 17, web site www.europa.eu.int.
31. Energy Information Administration, *International Energy Annual 1999*, DOE / EIA-0219(99) (Washington, DC, February 2001), Tables 2.5 and 5.4.
32. UK Department of Trade and Industry, *Conclusions of the Review of Energy Sources for Power Generation, and Government Response to Fourth and Fifth Reports of the Trade and Industry Committee Energy Review White Paper*, CM 4071 (London, UK, October 1998).
33. S. Barker, "UK Suppliers Will Keep the Lights On," *The Daily Telegraph* (February 5, 2001), p. 25; C.J. Levesque, "On the Origin of the Markets: Electricity Evolution in the U.K.," *Public Utilities Fortnightly* (July 15, 2001), pp. 48-54; G.T. Smith, "What Happened?—Lessons From Across the Seas: Deregulation Is Working Pretty Well in Britain; But It Has Taken a Long Time," *Wall Street Journal* (September 17, 2001), p. R.9.
34. E. Ewart, "The European Coal Industry: Hard Times for Coal," *Coal Age* (September 2001), p. 31.
35. International Energy Agency, *Coal Information 2001* (Paris, France, September 2001), Table 6.13.
36. Commission of the European Communities, *Proposal for a Council Regulation on State Aid to the Coal Industry* (Brussels, Belgium, July 25, 2001), pp. 24-25, web site www.europa.eu.int.
37. "Coal Industry Receives Additional Funds as EU Drafts New Aid Plan," *Financial Times: International Coal Report*, No. 530 (July 31, 2001), pp. 8-9.
38. Energy Information Administration, *International Energy Annual 1999*, DOE / EIA-0219(99) (Washington, DC, February 2001), Tables 2.5 and 5.4.
39. International Energy Agency, *Coal Information 1998* (Paris, France, July 1999), p. I.210.
40. International Energy Agency, *Coal Information 2001* (Paris, France, September 2001), pp. I.199-I.201; RAG Aktiengesellschaft, *Annual Report 2000* (Essen, Germany, June 2001), pp. 48-49, web site www.rag.de.

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

42. Energy Information Administration, *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001), Tables 2.5 and 5.4.

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

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

45. Energy Information Administration, *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001), Tables 2.5 and 5.4.

46. International Energy Agency, *Coal Information 1998* (Paris, France, July 1999), p. I.210.

47. E. Ewart and R. Marston, "Marketwatch: World Coal Trade and the Impact of Global Environmental Regulation," *Coal Age* (September 1, 2001).

48. International Energy Agency, *Coal Information 2001* (Paris, France, September 2001), Table 3.3a.

49. United Nations Framework Convention on Climate Change, *Report of the Conference of Parties on Its Third Session, Held at Kyoto from 1 to 10 December 1997, Kyoto Protocol to the United Nations Framework Convention on Climate Change*, FCCC/CP/1997/L.7/Add.1 (December 10, 1997), web site www.unfccc.de.

50. International Energy Agency, *Coal Information 2001* (Paris, France, September 2001), Tables 6.1 and 6.3.

51. J. Chadwick, "CIS Coal," *The Mining Journal* (June 1998); PlanEcon, Inc., *Energy Outlook for Eastern Europe and the Former Soviet Republics* (Washington, DC, October 1999), pp. 13-14.

52. "World Bank Approves Coal-Privatization Loan to Russia," *BBC Monitoring Former Soviet Union—Economic* (November 23, 2001).

53. H. van Zon, "The Reform of Ukraine's Energy Complex as a Precondition for Eliminating Ukraine's Energy Dependence." Paper presented at the Conference 2001 Confronting Change: North East England and Eastern European Coal Fields (Newcastle upon Tyne, United Kingdom, November 12-13, 2001), web site www.sunderland.ac.uk; "Ukraine: Country Profile," *Europe Review World of Information* (September 13, 2001); "Deadly Explosion in Ukrainian Mine Highlights Industry Collapse," *Agence France-Presse* (August 19, 2001); "Ukraine Mines Eye Entrepreneurial Future," *China Daily: North American Edition* (March 23, 2000), p. 6; and World Bank: Public Policy for the Private Sector, "Coal Industry Restructuring in Ukraine, The Politics of Coal Mining and Budget Crises," Note No. 170 (Washington, DC, December 1998), web site www.worldbank.org.

54. "Ukraine Turns to West for Mine Safety Funding: Ten Miners Still Missing After Sunday's Disaster," *Financial Times: USA Edition* (August 21, 2001), p. 3.

55. "Ukraine Industry in the Spotlight as Rescue Program Is Opposed," *Coal Week International* (October 15, 2001), p. 3.

56. "Coal Consumption in Ukraine To Rise 1.8 Times by 2010 and 2.7 Times by 2030," *Interfax (Moscow)* (November 27, 2001); "Ukrainian Paper Analyses Opposition to Reforms in Coal Sector," *BBC Monitoring Former Soviet Union—Political* (September 27, 2001); "Ukraine To Close 39 Mines," *World News Connection* (September 12, 2001); "Putin Visit to Urengoy Gas Field Seen Linked to Falling World Oil Price," *World News Connection* (November 20, 2001); "Russia Aims To Generate More Power With Coal, Leave Gas, Oil for Export," *Coal Week International* (January 22, 2001), p. 3.

57. Energy Information Administration, *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001), Table 2.5.

58. Energy Information Administration, *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001), Table 1.4.

59. Energy Information Administration, Office of Energy Markets and End Use, International Statistics Database; International Energy Agency, *Coal Information 2001* (Paris, France, September 2001).

60. "Coal Mining Improves Financial Performance in 2001," *Financial Times: International Coal Report*, No. 535 (October 9, 2001), pp. 9-10.

61. Reuters via NewsEdge Corporation, "Poland To Speed Up Mining Lay-Offs" (December 22, 1999); Associated Press, "Parliament Chamber Approves Coal Mining Restructuring Plan" (November 26, 1998).

62. Reuters, "World Bank Urges Faster Privatization in Poland," (November 14, 2001); World Bank, "Poland: World Bank Continues Support for Hard Coal Industry Restructuring," News Release No. 2002/050/ECA (Washington, DC, August 2, 2001), web site www.worldbank.org.

63. Energy Information Administration, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table A8.

64. "Ontario's IMO Forecasts Province's Electricity Supply Secure for Next 10 Years," *Foster Electric Report* (September 5, 2001); M. Mittelstaedt, "New Life for Old Reactors Fans Fears for Safety," *The Globe and Mail* (May 28, 2001), p. A1; Energy Information Administration, *Nuclear Power Generation*

and Fuel Cycle Report 1997, DOE/EIA-0436(97) (Washington, DC, September 1997), Table D1.

65. "Brooks Power Project Makes It Official With Alberta Govt," *International Coal Trade*, No. 1350 (October 1, 2001), p. 10; "Fording Inc. Lays Groundwork for Coal-Fired Units in Alberta," *Coal Week International* (October 1, 2001), p. 4.
66. F.G. Jáuregui D., "Steam Coal Requirements of CFE." Paper presented at the Western Coal Council's Pacific Coal Forum (Park City, UT, June 23-26, 1997).
67. "International Market Report," *International Coal Trade*, No. 1350 (October 1, 2001), p. 2; "International Market Report," *International Coal Trade*, No. 1348 (September 17, 2001), p. 3.
68. "International Market Report," *King's International Coal Trade*, No. 1194 (September 11, 1998), pp. 2-3.
69. "Iberdrola's $7.7-Billion Expansion Plan Targets Spain, Latin America," *Electric Utility Week* (May 14, 2001), p. 20; and "Market Chatter," *International Coal Trade*, No. 1328 (April 30, 2001), p. 16.
70. "Iberdrola's $7.7-Billion Expansion Plan Targets Spain, Latin America," *Electric Utility Week* (May 14, 2001), p. 20.
71. A. Harrup, "Mexico's State Utility Plans New Coal-Fired Power Plant," *Dow Jones Newswires* (July 3, 2001).
72. International Energy Agency, *Coal Information 2001* (Paris, France, September 2001), pp. III.37-III.38.
73. International Energy Agency, *Coal Information 2001* (Paris, France, September 2001), pp. III.36; Energy Information Administration, "Country Analysis Brief: South Africa," web site www.eia.doe.gov (December 2000).
74. "Kenya: Energy Ministry Sets Aside Money for Coal Prospecting," *BBC Monitoring Africa—Political* (November 20, 2000).
75. C. Akunna, "Ezeife Urges Igbo To Produce Coal-Fired Electricity," *Africa News Service* (December 14, 2001); K.U. Kalu, "Future of Coal Industry," *Africa News Service* (October 5, 2001); E. Imisim, "Government Gets $100m World Bank Credit for NEPA Reforms," *Africa News Service* (August 2, 2001).
76. "Tanzania: Government Plans To Develop Coal-Fired Power Station," *BBC Monitoring Africa—Political* (September 7, 2000).
77. "Largest IPP in Africa, Middle East Is Completed," *Power*, Vol. 145, No. 5 (September/October 2001), p. 16.
78. Web site www.worldsteel.org.
79. International Energy Agency, *Coal Information 2001* (Paris, France, September 2001), pp. I.88 and I.97; AME Research, web site www.ame.com.au.
80. "Tractabel's Gerasul Advances 350-MW Jacui; Will Boost Capital by $65-Million," *Global Power Report* (July 20, 2001), p. 12; D. Clifford, "Brazil—A Modern Mining Giant," *Mining Magazine* (July 1, 2001), p. 6.
81. "Brazil's Inepar To Exit Distributor's Celpa, Cemat, and Maybe Generation," *Electric Utility Week* (May 7, 2001), p. 21.
82. Energy Information Administration, "Puerto Rico Fact Sheet," web site www.eia.doe.gov (May 2001).
83. "AES Looks for 3-Year Supply," *McCloskey Coal Report*, No. 19 (October 4, 2001), p. 18; B.K. Schimmoller, "Fuel and Materials Handling: Moving It Without Losing It," *Power Engineering* (March 1, 2001), pp. 44-48.
84. Energy Information Administration, *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001), Tables 2.5 and 5.4; International Energy Agency, *Coal Information 2001* (Paris, France, September 2001), p. II.23.
85. "Sugozu Coal-Fired Thermal Plant in Turkey To Start Operating in Second Half of 2003," *Turkish News Digest* (October 22, 2001); "Construction Underway at Iskenderun," *Modern Power Systems* (May 1, 2001), p. 39; M. Woof, "Coal Power," *World Mining Equipment* (September 1, 2001), p. 12; S. Atalay, "Turkish Govt Signs $1.62 Bln Loan for 1400MW Power Project," *Dow Jones Newswires* (October 15, 1999).
86. "New Plant On Line," *Coal Week International* (February 26, 2001), p. 9; "Israel Looking to Asia, U.S., To Meet Growing Steam Coal Need," *Coal Week International* (November 13, 2000), p. 4.
87. "Israel Electric Receives Green Light To Construct New Coal-Fired Plant," *International Coal Trade*, No. 1346 (September 3, 2001), p. 15; T. Muscal and M. Meyer, "Lieberman Okays $1.3b Coal Power Plant Near Ashkelon," *The Jerusalem Post* (August 29, 2001), p. 12; R. Gelbfish, "Lieberman Approves Additional Coal Power Plant," *World News Connection* (August 28, 2001).
88. "Koreans Change Supply Focus," *Monthly Shipping Review SSY* (December 8, 2000), p. 4.
89. U.S. Federal Reserve Bank, "Foreign Exchange Rates (Monthly)," web sitewww.bog.frb.fed.us; International Monetary Fund, *International Financial Statistics Yearbook* (Washington, DC, various issues).
90. "Market Hits 29-Month Low," *Monthly Shipping Review SSY* (September 10, 2001), pp. 2-3.

91. "China Press: 2002 Coal Exports Put at 90-100M Metric Tons," *Dow Jones News Wires* (January 24, 2002).

92. "China's Coal Exports Up in Jan-Jun," Xinhua News Agency—CEIS (July 17, 1999); Z. Shaoqun, "Gov't To Increase Coal Exports," *China Daily* (July 9, 2000).

93. "China To Export 100 mt, Shenhua 24 mt," *McCloskey Coal Report*, No. 19 (September 21, 2001), pp. 23-24.

94. International Energy Agency, *Coal Information 2001* (Paris, France, September 2001), Table 4.2; Energy Information Administration, National Energy Modeling System run IEO2002.D010702A.

95. International Energy Agency, *Coal Information 1998* (Paris, France, July 1999), p. I.189.

96. "Japanese Coal Mine To Cease Operation," *International Coal Trade*, No. 1351 (October 8, 2001), p. 17; "Ikeshima Coal Mine Closed After 42 Years in Business," *Kyoda News* (November 28, 2001); K. Hall, "Ending Era, Japan's Last Coal Mine Shuts Down," Associated Press Newswires (January 30, 2002).

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

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

99. S. Wyatt, "Japan Fuels Changes in Coal Price," *Financial Times* (April 25, 2000), p. 42.

100. "Taking a Different VIU," *Financial Times: International Coal Report*, No. 530 (July 31, 2001), pp. 1, 3.

101. Energy Information Administration, *Annual Prospects for World Coal Trade 1991*, DOE/EIA-0363(91) (Washington, DC, June 1991), Table 1.

102. "Negative Influence From Tonne-Miles," *Monthly Shipping Review SSY* (September 10, 2001), p. 4.

103. S. Wyatt, "China Stakes Claim As Asia's Coal King," *Australian Financial Review* (May 16, 2001), p. 22; "China Rampant," *Monthly Shipping Review*, Vol. 554 (June 8, 2001), p. 4; "Increased Competition Forecast by ABARE," *Coal Week International* (June 25, 2001), p. 6.

104. "Expansion Begins at Richards Bay," *Coal Week International* (June 18, 2001), p. 7; "Which Way Will the Atlantic Market Flow," *Financial Times: International Coal Report*, No. 531 (August 14, 2001), pp. 20-21.

105. International Energy Agency, *Coal Information 2001* (Paris, France, September 2001), p. I.128.

106. International Energy Agency, *Coal Information 2001* (Paris, France, September 2001), pp. I.130 and I.132; AME Research, web site www.ame.com.au.

107. Energy Information Administration, National Energy Modeling System run IEO2002.D010702A.

108. "Reverberations," *Canadian Geographic* (January/February 2000), p. 15; J. Wong, "Blue Christmas," *The Globe and Mail* (December 22, 2001), p. F1.

109. "Facts About NSPI Coal Supply," *Nova Scotia Power* (May 16, 2001), web site www.nspower.ca.

110. Energy Information Administration, *Annual Prospects for World Coal Trade 1987*, DOE/EIA-0363(87) (Washington, DC, May 1987), Tables A2 and A3.

111. Energy Information Administration, *Coal Data: A Reference*, DOE/EIA-0064(93) (Washington, DC, February 1995), pp. 33-35; World Coal Institute, "Coal in the Steel Industry," in *Coal: Power for Progress*, Fourth Edition, web site www.wci-coal.com (March 2000).

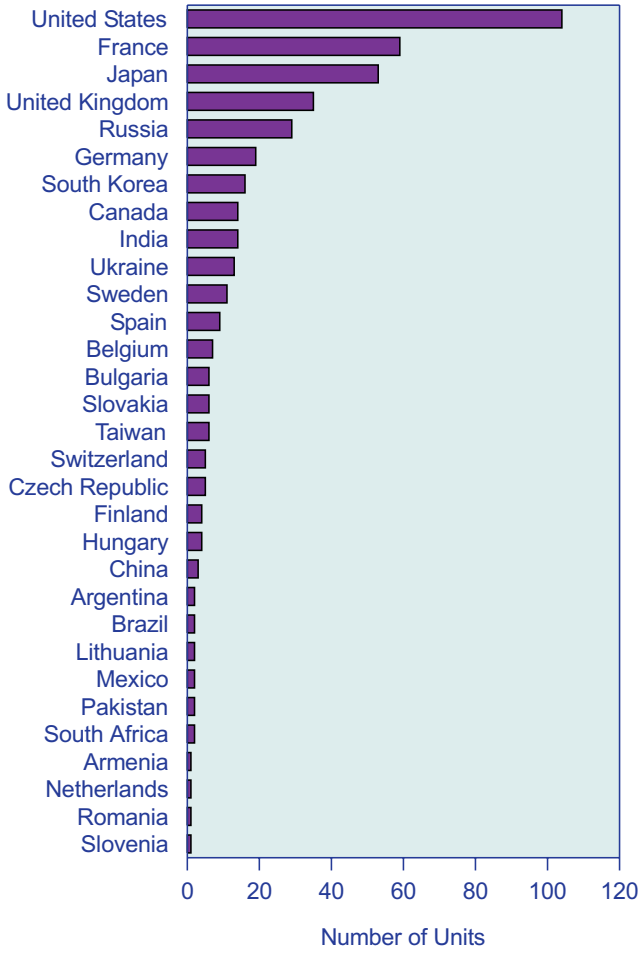
112. International Energy Agency, *Coal Information 2001* (Paris, France, September 2001), Tables 3.9 and 3.10.

Nuclear Power

Nuclear power is projected to represent a growing share of the developing world's electricity consumption from 1999 through 2020. New plant construction and license extensions for existing plants are expected to produce a net increase in world nuclear capacity.

World nuclear power capacity is projected to increase slightly over the forecast period, from 350 gigawatts in 2000 to 359 gigawatts in 2020. Most of the growth is expected in developing Asia, particularly China, where 17 new power plants are expected to be operational over the forecast period. In the industrialized nations, with few additional nuclear plants being built and a significant number of plant retirements expected, nuclear power capacity is projected to fall considerably, despite the fact that the projections include expected future life extensions for some of the nuclear power plants currently operating in the United States and other industrialized nations.

Figure 62. Operating Nuclear Power Plants Worldwide, 2000



Source: International Atomic Energy Agency, "Power Reactor Information System," web site www.iaea.org/programmes/a2/ (February 12, 2002).

Nuclear power plants generated electricity in 30 countries in 2000. A total of 438 nuclear power plants were in operation around the world, including 104 in the United States, 59 in France, and 53 in Japan (Figure 62). Six new reactors came online in 2000, and two were shut down. The new reactors included Angra 2 (in Brazil), Temelin 1 (Czech Republic), Rajasthan 3 and 4 and Kaiga 1 (India), and Chasnupp 1 (Pakistan) for a total of 3,056 megawatts of capacity [***1***]. The country with the largest share of electricity generated by nuclear power was France, at 76 percent (Figure 63). Belgium, Bulgaria, France, Hungary, Lithuania, Slovakia, South Korea, and Ukraine depended on nuclear power for at least 40 percent of their electricity generation.

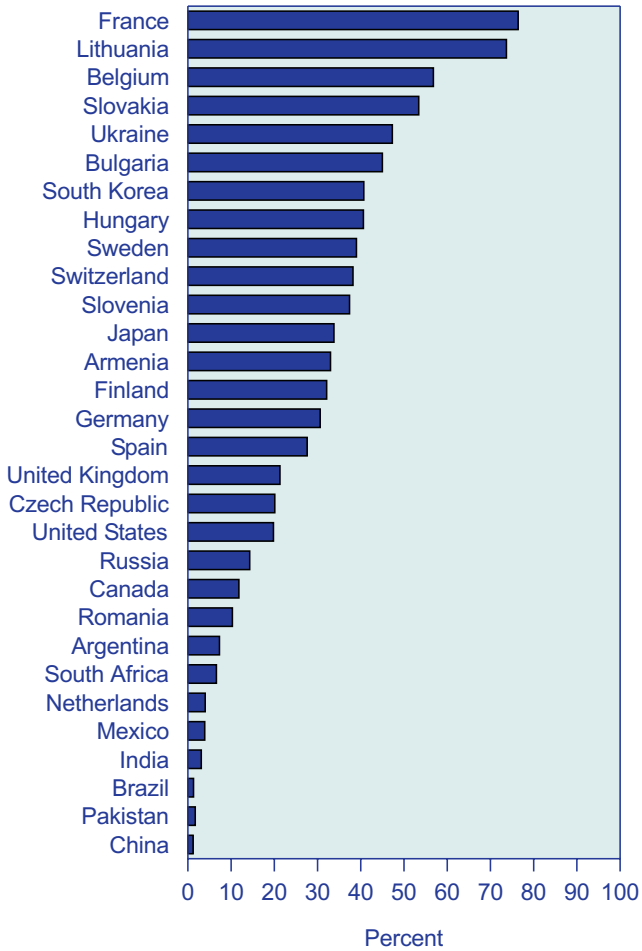
Nuclear power accounted for 16 percent of the world's total electricity supply in 1999. That share is projected to fall to 12 percent by 2020, primarily because the industrialized nations are expected to eschew the construction of new units while continuing to retire plants built in the 1970s and 1980s, during nuclear power's heyday. Nuclear power plant operating license extensions or the equivalent, which were first issued in the United States in 2000, are expected to be granted in other industrialized nations. In many countries, extending the operational life of a nuclear plant is a less formal procedure than in the United States, where the U.S. Nuclear Regulatory Commission (NRC) must approve license extensions. In some countries, extending a plant's operating life is a decision that is left primarily to the owner.

In developing Asia, 32 gigawatts of capacity is projected to be added by 2020 to the region's 23 gigawatts of nuclear capacity operating in 2000. China is expected to account for 14 gigawatts of net capacity additions (Table 17). There are currently 33 reactors under construction around the globe (Figure 64), half of which are being built in developing Asia. China accounts for 8 of the new units, South Korea 4, and India and Taiwan 2 each. There are no new plants currently under construction or on order in North America, South America, or Western Europe.

The *International Energy Outlook 2002* (*IEO2002*) reference case forecasts world net capacity at 359 gigawatts in 2020, or 9 gigawatts more than projected in the *International Energy Outlook 2001* (*IEO2001*) reference case. Projected U.S. nuclear capacity in 2020 is 16 gigawatts higher in the *IEO2002* forecast as a result of an expectation that the owners of most of the nuclear power plants now operating in the United States will seek relicensing and will continue operating the plants. The *IEO2002* forecast projects 3 gigawatts fewer retirements in 2020 overseas but also projects fewer new builds overseas than did the *IEO2001* forecast.

In many countries the decision to build a nuclear power plant is fraught with uncertainty. In many cases, nuclear power plants have been announced but their construction has been delayed or abandoned altogether. Some nuclear power plants have taken as little as 4 years to build; others have taken well over a decade. This chapter includes two examples illustrating the difficulties of forecasting nuclear capacity growth and how contemporary events necessitate frequent revisions of earlier forecasts. The box on page 94 discusses the issues (largely political) that are likely to determine the future of nuclear power in the United Kingdom, and the box on page 95 describes financial issues that cast doubt on the future of Ukraine's nuclear option.

Figure 63. Nuclear Shares of National Electricity Generation, 1999

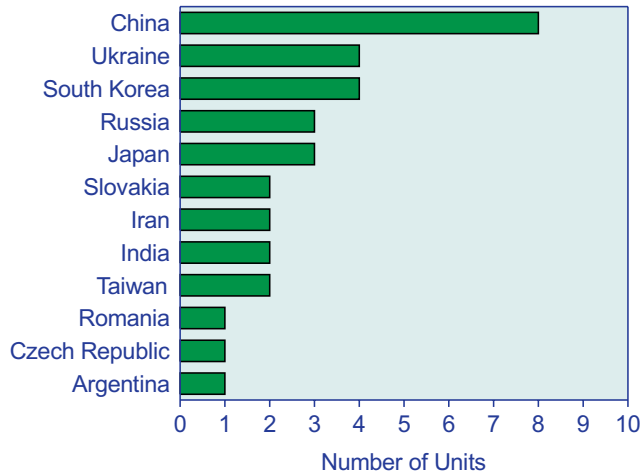


Source: Energy Information Administration, *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001).

The September 11, 2001, terrorist attacks on New York City and Washington, DC, gave rise to new concerns over the safety of the nuclear power plants now operating in the United States. Uncertainties about whether nuclear power plants and nuclear fuel storage facilities were at risk from a similar terrorist attack resulted in heightened security measures at all nuclear facilities around the country. Although a containment tower had in the past survived a head-on test crash of a military jet without major damage [***2***], it remains uncertain whether the same could be said of a head-on crash with a large commercial aircraft loaded with jet fuel. Containment vessels typically have 4 feet of steel-reinforced concrete along with a steel liner. Fuel storage facilities may be more prone to damage in the event of a head-on crash, in that they are not nearly so well protected.

After the September 11 attacks, the Federal Aviation Administration banned commercial airplanes from flying within 10 nautical miles of any nuclear facility. In many States, National Guard troops were deployed to protect power plants from possible terrorist attacks. It is uncertain what lasting impact these recent developments will have on the prospects for nuclear power either in the United States or overseas; the *IEO2002* forecast has not been adjusted to take into account any policy changes resulting from the events of September 11, 2001. One argument that may favor nuclear power is that continued or increased use of nuclear power for electricity generation would lessen U.S. dependence on

Figure 64. Nuclear Power Reactors Under Construction, 1999



Source: International Atomic Energy Agency, *Nuclear Power Reactors in the World 1999* (Vienna, Austria, April 2000).

Table 17. Historical and Projected Operable Nuclear Capacities by Region, 2000-2020
(Net Gigawatts)

Region	2000[a]	2005	2010	2015	2020
Reference Case					
Industrialized	**278.1**	**280.3**	**277.3**	**268.4**	**260.4**
United States	97.5	97.7	94.3	88.8	88.0
Other North America	11.4	15.0	15.0	15.0	15.0
Japan	43.5	44.3	47.8	50.8	53.4
France	63.2	62.9	62.9	62.9	64.4
United Kingdom	12.5	11.4	9.8	8.1	4.8
Other Western Europe	50.1	49.1	47.5	42.8	34.9
EE/FSU	**44.5**	**46.2**	**42.6**	**41.5**	**36.7**
Eastern Europe	10.7	11.7	10.1	10.1	10.7
Russia	19.8	21.7	21.3	20.3	14.8
Ukraine	11.2	11.2	11.2	11.2	11.2
Other FSU	2.7	1.6	0.0	0.0	0.0
Developing	**27.4**	**35.9**	**43.3**	**50.6**	**62.3**
China	2.2	6.6	9.6	11.6	16.6
South Korea	13.0	15.9	16.3	19.4	22.1
Other	12.2	13.5	17.5	19.6	23.6
Total World	**349.9**	**362.5**	**363.2**	**360.6**	**359.4**
Low Growth Case					
Industrialized	**278.1**	**273.9**	**264.1**	**239.9**	**217.1**
United States	97.5	97.7	94.3	86.4	85.6
Other North America	11.4	11.4	11.4	10.1	10.1
Japan	43.5	44.0	46.2	42.9	38.7
France	63.2	62.9	62.9	61.1	53.0
United Kingdom	12.5	11.0	8.1	4.2	1.2
Other Western Europe	50.1	46.9	41.2	35.3	28.5
EE/FSU	**44.5**	**43.3**	**36.7**	**27.9**	**17.2**
Eastern Europe	10.7	10.5	10.1	10.1	7.7
Russia	19.8	20.4	15.5	11.2	8.6
Ukraine	11.2	11.2	11.2	6.7	1.0
Other FSU	2.7	1.2	0.0	0.0	0.0
Developing	**27.4**	**33.0**	**38.7**	**42.8**	**44.5**
China	2.2	6.6	8.6	9.6	10.6
South Korea	13.0	14.9	16.3	18.5	20.2
Other	12.2	11.6	13.9	14.7	13.7
Total World	**349.9**	**350.2**	**339.6**	**310.7**	**278.8**
High Growth Case					
Industrialized	**278.1**	**284.8**	**283.1**	**293.1**	**301.5**
United States	97.5	97.7	95.4	89.9	89.1
Other North America	11.4	15.0	15.0	15.0	17.0
Japan	43.5	46.7	48.7	63.8	68.8
France	63.2	63.2	62.9	64.4	64.4
United Kingdom	12.5	12.3	11.0	10.6	12.4
Other Western Europe	50.1	50.1	50.1	49.5	49.9
EE/FSU	**44.5**	**49.2**	**50.5**	**51.7**	**55.8**
Eastern Europe	10.7	12.5	11.9	11.1	13.0
Russia	19.8	22.7	23.9	26.1	26.2
Ukraine	11.2	11.2	13.1	13.1	15.0
Other FSU	2.7	2.7	1.6	1.4	1.6
Developing	**27.4**	**37.9**	**51.6**	**66.6**	**83.0**
China	2.2	7.6	11.6	18.6	20.6
South Korea	13.0	16.8	19.7	21.4	26.2
Other	12.2	13.5	20.3	26.6	36.2
Total World	**349.9**	**371.9**	**385.2**	**411.3**	**440.4**

[a]Status as of December 31, 2000. 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 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001). **Foreign:** Based on detailed assessments of country-specific nuclear power programs.

United Kingdom Waxes and Wanes on Nuclear Power

In part because it is the most politicized of all electricity generation technologies, future nuclear power capacity is particularly difficult to forecast. The difficulty arises from a number of issues, such as safety, nuclear proliferation, waste disposal, plant decommissioning, and the cost of future plant construction. In recent years, some government officials and industry leaders have shown renewed interest in building additional nuclear power plants in countries where the movement away from nuclear power appeared inexorable. Nevertheless, the *IEO2002* reference case projects that a number of nuclear power plants currently planned in several nations over the forecast horizon will not be built, and that a fundamental reversal of the trend toward retirement of existing nuclear power plants—a trend that has been evident since the early 1990s—will not take place.

One country where new nuclear construction is now thought to be a possibility is the United Kingdom. In the *IEO2002* reference and low nuclear case forecasts, no new nuclear power plants are expected to come online in the United Kingdom by 2020; however, the high nuclear case projects that three new 1,000-megawatt units will be built and operating by the end of the forecast period. Currently, the UK government has no stated plans to build additional nuclear power plants, although there has been renewed public debate on the efficacy of nuclear power, and the current Labor party government appears to have softened its prior opposition. The *IEO2002* reference and low nuclear case forecasts assume that those factors in themselves are not enough to overcome all the obstacles currently arrayed against the further development of nuclear power in the United Kingdom.

One of the foremost difficulties in forecasting the future role of nuclear power is that different political parties often have opposing views on the subject. In many cases, future election results could alter the course of nuclear power, as they have done in the recent past. Germany's decision to abandon nuclear power, for instance, is clearly the result of the election of the Social Democrats and their anti-nuclear allies, the Green party. When the Conservative party government of Margaret Thatcher was in office in the United Kingdom, nuclear power was viewed as a viable future contributor to new electricity generation. When Labor assumed office, it was felt that Labor's stated opposition to nuclear power would become government policy. For some time, however, the government of Prime Minister Tony Blair has left open the option that nuclear power would continue to play a role in the nation's electricity supply. Britain's support of the Kyoto Protocol was one factor forcing a reevaluation of the nuclear option: if the United Kingdom abandoned its nuclear option, compliance with the Kyoto Protocol would be more difficult. The initial Blair cabinet even included an energy minister, John Battle, who had come out in support of building new reactors.

In February 2002, a UK government review of energy was released. The review called for a national debate on nuclear power and for an examination of "low waste, modular designs of nuclear reactors" and urged the government to "continue to participate in research aimed in this direction."[a] Moreover, the chief executive of the UK nuclear power company, BNFL, has urged the government to promote the building of nuclear power plants.[b]

There are still several reasons why the UK is unlikely to renew its promotion of nuclear power as a source of electricity generation. Two reports completed in the fall of 2001 by the Labor government pointed out that nuclear power was much more costly than wind or biomass, and that increased energy efficiency and combined heat and power were preferable options. Concerns over nuclear proliferation and terrorism in the post-September 11 world may also have inspired a change of heart.

Since the late 1980s, the unexpected large construction cost overruns for Britain's nuclear power plants have led to a reevaluation of the future role of nuclear power in the nation's energy mix. As in the United States, most of the UK electric utility industry's stranded cost problem stemmed from past investments in nuclear energy, largely as a result of cost overruns in the construction of nuclear facilities and unforeseen spent-fuel reprocessing and disposal liabilities, as well as decommissioning costs.

Only one nuclear reactor (Sizewell B) has come online in the United Kingdom since 1988, and it has been controversial. During construction, the capital costs for Sizewell B escalated by 35 percent; and when the plant came online it generated electricity at a cost that was twice what the UK electricity pool was charging. Construction delays have also been a problem for the UK nuclear industry. The Dungeness B reactors, for instance, took 22 years to complete.

(continued on page 95)

[a]"Minister Says UK Energy Review Keeps New Nuclear Option Open," *NucNet: The World's Nuclear News Agency*, Vol. 65, No. 2 (February 14, 2002).

[b]P. Brown and D. Gow, "UK 'Needs Another 20 Nuclear Stations,'" *Guardian Unlimited* (September 7, 2001), web site www.guardian.co.uk/Archive/Article/0,4273,4252099,00.html.

United Kingdom Waxes and Wanes on Nuclear Power (Continued)

Since the reform of the UK electric power industry was started in 1989, its electricity market has developed into one of the most competitive around the globe. This too does not augur well for nuclear's future in the UK electricity supply industry. For example, a 1995 government white paper concluded that, in a competitive private market, no one would invest in new nuclear capacity and indicated that the government would not provide state subsidies to ensure new construction of nuclear plants.[c]

In the *IEO2002* forecast, natural gas is expected to accommodate much of the growth in UK electricity demand to the year 2020, obviating the need for construction of additional nuclear units. Natural gas remains a viable future source of energy for electricity production in the United Kingdom. Despite increases in consumption over the past 20 years, the country's natural gas reserves have risen by 7 percent. Moreover, wholesale natural gas prices in the United Kingdom generally have tracked below U.S. natural gas prices.

[c]G. MacKerron, "Nuclear Power Under Review," in *The British Electricity Experiment, Privatization: The Record, the Issues, the Lessons* (London, UK: Earthscan PublicationsLimited, 1996), pp. 159-160.

Can Ukraine Finance Nuclear Power?

In most of the industrialized nations, the decision to continue to develop nuclear power as a source of electricity hinges on such factors as the economic viability of a nuclear power plant relative to coal, natural gas, or other sources of electricity. Other considerations include power plant operating safety, decommissioning costs, waste disposal, and concerns about nuclear arms proliferation. In other countries, such as Ukraine, obtaining project funding has been the most critical issue in the development of a domestic nuclear power industry.

Although Ukraine's 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 former Soviet Union. In 1995, the European Bank for Reconstruction and Development (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.[a] 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." Over the course of several years, three outside consulting firms provided analyses of the viability of K2 and R4. Two concluded that completion of the plants represented the least-cost option, and one suggested that economics argued against their completion.[b] Several Western European environmental groups and political parties have also opposed the construction of K2 and R4.

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, and $50 million from the Ukranian government.[c] However, as coordinator of the loan package, EBRD's funding became critical to the future survival of the project. Energoatom, the Ukraine nuclear power utility, and the EBRD had a difficult time negotiating a loan agreement. Initially, the EBRD approved a $215 million loan in December 2000 for the completion and safety upgrade of K2 and R4, pending certain conditions involving safety and funding availability. In December 2001, however, loan negotiations between the EBRD and the Ukrainian government foundered over an inability to agree on a future rate structure for sales of electricity from the two plants. Although it remains unclear whether K2 and R4 will be completed, the Ukraine's experience in trying to finance and build the plants is an example of the difficulties some nations face in their efforts to develop a nuclear power industry.

[a]Chernobyl 4 was shut down after the accident in 1986. Unit 2 was shut down after a turbine fire in 1991, and unit 1 was closed in 1997. Unit 3 was shut down in 2000.

[b]The initial study was conducted by a German firm, Lahmeyer, which found completion to be the least-cost option. The second study, conducted by a group of energy experts (the Surrey Panel) argued against completion. The third study was conducted by Stone and Webster, a U.S.-based engineering and construction firm.

[c]European Bank for Reconstruction and Development, "EBRD Approves Ukranian Nuclear Power Project Subject to Strict Conditions" (December 7, 2000), web site www.ebrd.com.

energy imports and thus provide greater national security. The "improved national security" argument can be taken only so far, however, given that the only imported fuel that competes significantly with nuclear power is natural gas, and almost all U.S. natural gas imports come from Canada. In other countries, nuclear power may well be considered a more secure form of electricity production, particularly by those nations heavily dependent on energy imports for electricity production. For instance, Japan relies on imported oil and natural gas for 38 percent of its electricity production, and 79 percent of its oil imports and 20 percent of its natural gas imports come from the Middle East [***3***].

Nuclear power first became a major source of electricity production in the 1970s. Nuclear power consumption worldwide grew from 188 billion kilowatthours in 1973 to 1,843 billion kilowatthours in 1989 [***4***]. By the 1990s, however, the growth of nuclear power consumption had begun to slow, and it is expected to level off by 2010. No lasting orders for new plants have occurred in Austria, Hungary, Italy, Mexico, the Netherlands, Switzerland, or the United States since 1973 [***5***]. Thus far, however, only Germany, Lithuania, Sweden, and Ukraine have committed to the early retirement of some if not all of their nuclear power plants. All other nations seeking to reduce their reliance on nuclear power intend to do so through attrition and by not building any new nuclear power plants. Still, many nations may find that viable alternatives to nuclear power are more difficult to develop than anticipated. Sweden, for instance, after committing to the closure of its Barsebäck nuclear power units by 2001, has delayed the closure of Barsebäck 2 until 2003.

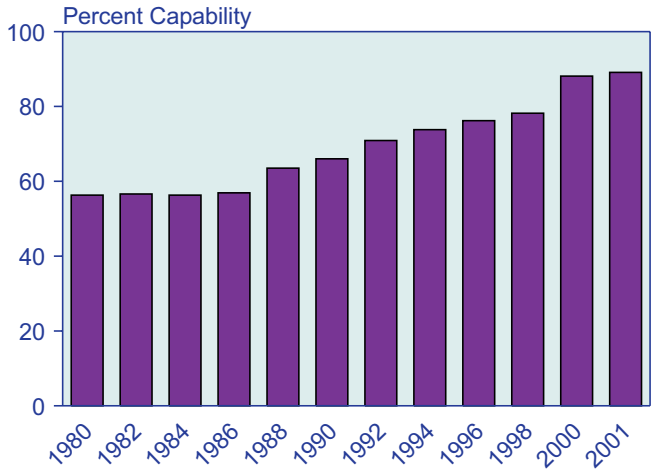
The Economics of Nuclear Power

There has been a significant improvement in the economics of nuclear power over the past several years. Capacity factors in the United States, for instance, which averaged 56.3 percent in 1980, grew to 89.1 percent in 2001 (Figure 65). Since the 1970s and 1980s, the average interval between refuelings for U.S. nuclear units has increased to 18 months from 12 months, resulting in less frequent outages [***6***], and since 1990 the average refueling cycle has fallen from 100 days to 80 days [***7***]. Overseas, capacity factors have also improved measurably. For those developed nations with nuclear power units in operation in both 1980 and 1999 (including the United States), the average capacity factor rose from 59 percent to 77 percent (Figure 66).

One of the ways to increase the capacity factor of a nuclear unit is to have fewer scheduled and unscheduled shutdowns; and improved operational safety has been an important factor in reducing shutdowns. Another means of increasing the output of nuclear power plants is to implement a power uprate, which can be viewed as increasing the absolute capacity of a plant rather than its utilization rate. Since the 1970s, the NRC has approved 62 uprates of U.S. nuclear plants, adding the equivalent of two large nuclear units [***8***]. Power uprates are typically achieved through plant upgrades, including investments in such items as pipes, heat exchangers, pumps, transformers, and generators.

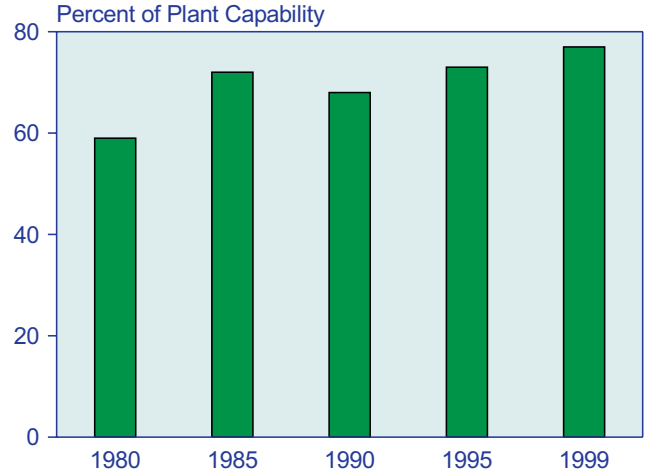
Recently, the U.S. nuclear power industry has witnessed an unprecedented merger and acquisition spree, seeing roughly one-fourth of the industry change ownership and resulting in a much more concentrated industry.

Figure 65. U.S. Nuclear Unit Capacity Factors, 1980-2001



Source: Energy Information Administration, *Monthly Energy Review*, DOE/EIA-0035(2000/02) (Washington, DC, February 2002), p. 113.

Figure 66. Nuclear Unit Capacity Factors in Developed Nations, 1980-1999



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

One possible motivation for consolidation is the belief on the part of the acquisition companies that a company with several power plants can operate them more efficiently than a company operating only one or a few plants. This also may lead to future efficiency improvements.

Although increased capacity utilization and uprates have improved the economics of nuclear power, for most nations and under most economic assumptions, nuclear power currently is a relatively expensive option for electricity generation when compared with natural gas or coal. A recent study by the International Energy Agency (IEA) on the relative competitiveness of natural gas, nuclear power, and coal among members of the Organization for Economic Cooperation and development (OECD) [***9***] examined various operating costs, capital costs, plant decommissioning costs, and the costs of waste disposal (see box on page 98). The study compared existing technologies and not future technologies. Expectations are that future nuclear power plants will see significant efficiency gains, although gains are also expected for natural gas, coal, and renewables.

In terms of operating costs, the IEA study concluded that nuclear power plants were competitive against coal and natural-gas-fired generation units. Natural-gas-fired units averaged 2.2 to 4.1 cents per kilowatt hour, coal plants between 1.9 and 3.3 cents per kilowatthour, and nuclear between 0.8 and 3.2 cents per kilowatthour (Table 18).[16] The fuel costs (per kilowatthour of generation) for a nuclear power plant are significantly lower than those for coal or natural gas plants.

Capital costs, however, are another matter. The IEA study looked at different plants operating in various member countries (Table 19). In capital-intensive industries like electricity generation, interest rates play a key role in determining the relative economics of different generation fuel sources. The capital costs of a new nuclear unit are substantially higher than those for new natural gas and coal units. Interest rates vary across countries, as do other factors that affect the relative costs of nuclear power, including labor costs, material and equipment costs, regulation, and infrastructure.

The IEA study assumed three discount rates, 0 percent (i.e., the overnight capital cost), 5 percent, and 10 percent. (As a point of comparison, the U.S. prime rate has averaged 9.30 percent since 1970 [***10***].) Due to their higher construction costs, the relative cost of nuclear power plants is much more sensitive to changes in interest rates than are the costs of coal or natural gas plants. For a French-built pressurized-water reactor, capital costs averaged $1,636 per kilowatt at 0 percent, $1,988 per kilowatt at 5-percent interest, and $2,280 per kilowatt at 10-percent interest. It should be noted that the length of time to build a nuclear plant sometimes far exceeds the average. Although nuclear power plants can theoretically be built (and have been built) in 4 years [***11***], the IEA study notes that in the aftermath of the Three Mile Island accident in Pennsylvania, the average length of time to construct a U.S. power plant was 12 years.

Table 18. Projected Operating Costs of Nuclear, Coal, and Natural Gas Power Plants
(U.S. Cents per Kilowatthour)

Country	Nuclear	Coal	Natural Gas
Canada . . .	0.8	1.9	2.2
Finland	1.5	2.3	3.0
France	1.5	3.3	3.9
Japan	3.2	3.2	4.0
Korea	1.4	2.3	3.7
Spain	1.9	2.9	4.1

Source: International Energy Agency, *Energy Prices & Taxes, Quarterly Statistics, Second Quarter 2000* (Paris, France), p. xiii.

Table 19. Projected Operating Costs of Nuclear Power Plants
(U.S. Cents per Kilowatthour)

Country	Plant Type	Plant Net Capacity (Megawatts)	Total Capital Costs (Dollars per Kilowatthour)		
			Overnight Capital Cost	5% Discount Rate	10% Discount Rate
Canada . . .	Candu	1,330	1,697	2,139	2,384
Canada . . .	Candu	1,762	1,518	1,878	2,053
Finland	BWR	1,000	2,256	2,516	2,672
France	PWR	1,460	1,636	1,988	2,280
Japan	BWR	1,303	2,521	2,848	3,146
Korea	PWR	1,000	1,637	1,924	2,260
Spain	PWR	1,000	2,169	2,540	2,957

Candu = Canada Deuterium Uranium Reactor, which is a Canadian nuclear power plant design. BWR = Boiling Water Reactor. PWR = Pressurized Water Reactor.

Note: Technology to become commercially available by 2005-2010.

Source: International Energy Agency, *Energy Prices & Taxes, Quarterly Statistics, Second Quarter 2000* (Paris, France), p. xiii.

[16]Prices varied for different nations in the study, depending on domestic prices for coal and natural gas.

Nuclear Waste Disposal

Countries approach nuclear waste disposal in various ways (see table below). France, Japan, and the United Kingdom, for instance, rely on reprocessing that separates the spent reactor waste into both a recyclable fuel and a highly concentrated waste—a "closed fuel cycle" that produces both plutonium and uranium. The United States, Canada, and Sweden directly dispose of spent uranium from power reactors in an "open fuel cycle." Several countries have yet to commit to any form of waste disposal, relying instead on interim storage for the foreseeable future. Although a long-term solution to storing nuclear waste is critical, short-term storage is an adequate solution for several years. In 1997, reactor storage facilities stored 87,756 tons of nuclear fuel worldwide, well beneath their storage capacity of 147,868 tons of spent fuel.[a]

Management of Spent Fuel by Country

Country	Deferred Decision	Direct Disposal	Reprocessing
Argentina	x		
Belgium	x		x
Brazil	x		
Bulgaria	x		x
Canada		x	
China			x
Czech Republic	x	x	x
Finland		x	
France			x
Germany		x	x
Hungary	x		x
India			x
Italy	x		x
Japan			x
South Korea	x		
Lithuania		x	
Mexico	x		
Netherlands			x
Pakistan	x		
Romania		x	
Russia			x
Slovakia		x	x
Slovenia	x		
South Africa		x	
Spain		x	
Sweden		x	
Switzerland	x		x
United Kingdom			x
Ukraine	x	x	x
United States		x	

Source: International Atomic Energy Agency, "Rising Needs Management of Spent Fuel at Nuclear Power Plants," web site www.iaea.or.at/worldatom/inforesource/bulletin/bull401/article6.html.

In a closed fuel cycle, waste disposal involves the production of mixed oxide (MOX) fuel, a combination of plutonium and uranium. About 1 percent of the spent fuel coming out of a reactor is plutonium, which can be mixed with uranium to form MOX or used as a fuel for a breeder reactor.[b] France, Belgium, and the United Kingdom account for most MOX recycling. Currently, a multinational consortium is building a MOX plant in Russia with the intention of recycling plutonium derived from destroyed nuclear weapons. An advantage of using MOX as a fuel is that its use should lead to a reduction in plutonium inventories, which could lessen the threat of nuclear weapons proliferation. The disadvantage is that it also results in the production of plutonium, which some fear could be used in the construction of atomic weapons.

France began to reprocess its spent commercial nuclear fuels in 1958, Germany in 1971, the United Kingdom in 1964, Belgium in 1966 (shut down in 1974), Japan in 1981, and the former Soviet Union in 1978. The United States built three commercial reprocessing facilities in the 1970s, but a moratorium was placed on nuclear reprocessing in 1977. Although the moratorium was lifted in 1981, by then the economics of reprocessing had become less viable because uranium prices had fallen.

There is a general consensus that stable, deep, geological formations are the best locations to store high-level nuclear waste. Most nations have identified potential underground storage sites and have conducted geological and geophysical tests as to the suitability of the proposed sites. Currently, however, no underground storage sites have progressed beyond the planning stage. Although in February 2002 President Bush authorized construction of the Yucca Mountain nuclear waste depository in the United States, the U.S. Congress may yet oppose the facility. The greatest concern over the storage of high-level nuclear wastes is that over the tens of thousands of years for which the waste will be stored in containers, it could eventually leak and leach its way into the water table. In addition to the radioactivity it releases, high-level nuclear waste also produces great amounts of heat, necessitating additional efforts at isolation. As a result, the wastes

(continued on page 99)

[a]P. Dyck and M.J. Crijns, "Rising Needs: Management of Spent Fuel at Nuclear Power Plants" (International Atomic Energy Agency, April 1998), web site www.iaea.or.at/worldatom/inforesource/bulletin/bull401/article6.html.

[b]I. Hore-Lacy, *Nuclear Electricity*, Sixth Edition (Canberra, Australia: Uranium Information Centre and Minerals Council of Australia, August 2000), web site www.uic.com.au/ne.htm.

The IEA study concluded that, depending on the price of various operations and maintenance costs (which are heavily dependent on fuel costs, particularly for coal and natural gas) and the cost of capital (which affects nuclear disproportionately), the economics of natural gas, coal, and nuclear plants differ considerably. Assuming a 5-percent discount rate, nuclear power plants are estimated to be more efficient than coal or natural gas plants in 5 of 9 countries for which data on all three fuels were available. These countries are typically those with high natural gas prices. At a 10-percent discount rate, nuclear power is less efficient in every country. The IEA has also conducted case studies on countries such as China, India, South Korea, Pakistan, and Vietnam and has concluded that nuclear power in those countries was never the cheapest form of electricity production [***12***].

Although currently nuclear power plants are in general not competitive with other sources of electricity, future gains in their efficiency are expected. According to a publication sponsored by the U.S. Department of Energy, *A Roadmap To Deploy New Nuclear Power Plants in the United States by 2010*, which included data from the U.S. nuclear industry on nuclear power plant designs that could be deployed by 2010, "new nuclear power plants can be deployed in the U.S. in this decade, provided that there is sufficient and timely private-sector financial investment." The report also noted that "although conditions are currently more favorable for new nuclear plants than in many years, economic competitiveness in a deregulated electricity supply structure remains a key area of uncertainty with respect to near term deployment potential . . . . [T]here are excellent new nuclear plant candidates that build on the experiences of existing reactors in the U.S. and around the world . . . . [T]hose that are most advanced in terms of design completion and approval status appear to be economically competitive in some scenarios, but not all" [***13***].

Regional Developments

Western Europe

Western Europe relied on nuclear power for 35 percent of its electricity in 1999. Nuclear's share of the Western European electricity market is expected to fall to 24 percent by 2020. Currently, among European countries, only France and Finland have shown any intent to expand their nuclear power industries. Most of the other nations of Western Europe have decided either to curtail

Nuclear Waste Disposal (Continued)

need to be stored for several years in steel-lined cooling pools or aboveground vaults before being transported to long-term waste depository sites.

The physical amount of waste produced thus far by all nations' nuclear power plants is not considered large. For the United States, for instance, it has been estimated that all the wastes from power reactors that have accumulated since the advent of civilian nuclear power production could be stored in a football-field-sized area roughly five yards deep.[c] Nevada's Yucca Mountain, which is scheduled to begin accepting commercial radioactive waste in 2010, is one of the furthest along worldwide, President Bush is the first to officially approve a site.[d] In the meantime, most, if not all, nuclear waste from U.S. power reactors is being stored on site at 70 nuclear power plants and two storage facilities. In addition, three low-level nuclear waste sites are in operation in South Carolina, Utah, and Washington.[e] The U.S. commercial nuclear industry creates about 2,000 metric tons of spent fuel per year, and about 40,000 metric tons of spent fuel are currently in temporary storage.[f]

Other nations with nuclear generating stations face similar storage issues. Underground repository sites are being planned for Belgium (2030), Canada (2025), Finland (2020), France (2020), Germany (2010), Spain (2020), Sweden (2008), and Switzerland (2020). As in the United States, most high-level waste overseas is currently stored on site at nuclear reactors.

Russia appears to be entering the business of storing other nations' high-level nuclear waste. On July 11, 2001, Russian President Vladimir Putin signed into law a measure exploring a plan to import and store other countries' nuclear wastes. Putin authorized a study to determine the long-term environmental impact of such storage. It has been estimated that Russia could earn as much as $20 billion over a decade by storing the nuclear wastes of countries whose own waste disposal efforts have made little progress.[g]

[c]Nuclear Energy Institute, "Nuclear Waste Disposal: Resources: Used Nuclear Fuel Management," web site www.nei.org (January 2002).

[d]E. Pianin, "Nevada Nuclear Waste Site Affirmed," *The Washington Post* (February 16, 2002), p. A1.

[e]M. Holt, "IB92059: Civilian Nuclear Waste Disposal," Congressional Research Service Report, web site cnie.org / NLE / CRSreports (U.S. Library of Congress, July 30, 2001).

[f]M. Holt, "IB92059: Civilian Nuclear Waste Disposal," Congressional Research Service Report, web site cnie.org / NLE / CRSreports (U.S. Library of Congress, July 30, 2001).

[g]Washington Nuclear Corporation, Nuke-Energy.com, web site www.nuke-energy.com / data / other / russian_president.html.

further development of nuclear power or to abandon it entirely. Belgium, Germany, the Netherlands, Spain, Sweden, and Switzerland have made past commitments to gradual phaseouts of their nuclear power programs, although those commitments have been difficult to carry through, as described below.

Sweden and Germany have adopted the most aggressive plans to end their nuclear power programs. In 1980, Sweden committed to a scheduled 40-year phaseout of nuclear power, and in November 1997 the Swedish parliament approved a plan to shut down two of the nation's twelve nuclear reactors, Barsebäck 1 and Barsebäck 2, which accounted for 12 percent of Sweden's nuclear generation capacity. Barsebäck 1, a 615-megawatt reactor that began commercial operation in 1975, was shut down in November 1999, more than a year after the scheduled closing date of July 1998. Barsebäck 2, completed in 1977, was initially scheduled to be closed in July 2001, but in August 2000 the Swedish government announced that the Barsebäck 2 closure would also be delayed until 2003, and then only if secure sources of electricity could be obtained [***14***]. After closing Barsebäck 1, Sweden replaced the lost electricity generation with imported power from a coal-fired plant in Denmark, causing an increase in Western Europe's total carbon dioxide emissions.

In June 2000, Germany's electricity industry agreed to phase out its nuclear power plants ahead of schedule [***15***]. The plan calls for the shutdown of all of Germany's reactors after they have operated for 32 years. Accordingly, the final plant closure would occur in the mid-2020s. Germany's ruling government minority coalition partner, the environmentalist Green party, had favored a 10-year phaseout. The Social Democratic German Chancellor, Gerhard Schroeder, initially favored a 20-year phaseout but reached a compromise with the electric utility industry. The German government also decided eventually to stop the foreign reprocessing of its spent nuclear fuels, but that decision was rescinded in early 2001, ending a 3-year moratorium on spent fuel shipments to foreign reprocessing plants.

There has been some recent apparent backtracking on the move away from dependence on nuclear power as a source of electricity. In Italy, the interim head of the nation's Environmental Protection Agency (Anpa) stated that there was "wide support within the country's scientific community for review of a possible re-emergence of nuclear energy in Italy" [***16***]. Similarly, the European director general for energy, Francois Lamoureux, stated that the use of nuclear is "unavoidable in aiding security of supply and tackling climate change" [***17***]. Martin Villa, the chairman of the Spanish Electricity Company Endesa, called for a reopening of the debate on new plant construction [***18***]. The Tony Blair government in the UK initially stated that it did not want an expansion of nuclear power; however, for some time the Blair government has left open the possibility that it would reverse that stance.

Japan

The Japanese government and electricity industry remain committed to building new commercial nuclear power reactors in the future, despite some public concern over operational safety. The *IEO2002* reference case projects that the nuclear share of Japan's total electricity generation will remain stable at about one-third through 2020.

Developing Asia

Alone among world regions, developing Asia is expected to see rapid growth in nuclear power. Nuclear power plants are currently in operation in China, India, Pakistan, South Korea, and Taiwan, and in the *IEO2002* reference case developing Asia is expected to more than double its nuclear capacity by 2020. Consumption of energy from nuclear power plants in developing Asia is projected to increase from 160 billion kilowatthours in 1999 to 425 billion kilowatthours in 2020. Increases in nuclear generating capacity are expected for all the developing Asian nations that currently have nuclear power plants in operation. By 2020, developing Asia is projected to account for 15 percent of the world's nuclear power capacity, up from 6 percent in 1999.

China and India are expected to show the most rapid growth in nuclear power capacity over the forecast period. China, which had 2,177 megawatts of capacity in 2000, is expected to increase its capacity to 16,607 megawatts by 2020. India is also expected to show a marked increase in nuclear power capacity. India, which currently has 2 nuclear power plants under construction, is expected to increase its capacity from 2,301 megawatts in 2000 to 6,451 megawatts by 2020.

IEO2002 expects substantial additional nuclear capacity to be added to the South Korean nuclear power sector over the forecast period. The additions projected are only slightly less than those forecast by the South Korean government or the state-owned national utility, KEPCO. In 1999, the South Korean nuclear power industry had 12,990 megawatts of capacity. By 2020, South Korea's nuclear power capacity is expected to rise to 22,125 megawatts.

North America

United States

The United States is expected to reduce its reliance on nuclear power significantly over the forecast period, from 20 percent of total electricity generation in 1999 to less than 15 percent in 2020. Only a few years ago it seemed likely that there would be numerous early

closures of nuclear power plants in the United States; however, several companies have recently applied to the NRC for extensions of reactor operating licenses, and as many as 90 percent of all operating plants could eventually be relicensed [**19**]. Reductions in operating costs over the past decade have made nuclear plants more competitive, even as electricity markets are increasingly being deregulated.

The Bush Administration's National Energy Policy favors expanding the role of nuclear power by, as stated in the report of the National Energy Policy Development Group, "encouraging the Nuclear Regulatory Commission to facilitate efforts by utilities to expand nuclear energy in the United States by uprating existing power plants safely . . ." and by encouraging "the NRC to relicense existing nuclear plants . . ." by directing the DOE and EPA to "assess the potential of nuclear to improve air quality . . . to increase resources as necessary for the nuclear safety enforcement in light of the potential increase in generation . . . to use the best science to provide a deep geologic repository for nuclear waste . . . to support legislation clarifying that qualified funds set aside by plant owners for eventual decommission will not be taxed as part of the transaction . . . to support legislation to extend the Price Anderson Act" [**20**], which limits a nuclear power plants liability in the case of an accident. In 2001, the Department of Energy's Office of Nuclear Energy, Science and Technology solicited proposals from the civilian nuclear electricity industry to conduct scoping studies "of potential sites for the deployment of new nuclear power plants" [**21**].

In the United States, some utilities have come out in favor of building new units and perhaps resurrecting units already shut down. In March 2001, the Tennessee Valley Authority (TVA) began reconsidering the restarting of Browns Ferry nuclear plant, which was shut down in 1985. In December 2001, the TVA announced that a "preferred option" is to extend the operation of all three Browns Ferry units [**22**]. Exelon Corp, the largest producer of nuclear power in the United States, has been discussing with the NRC the construction of new nuclear plants and announced that it is considering restarting one or both nuclear reactors at its Zion site (in Illinois), which was shut down in 1998. Recently, the NRC has approved three new versions of reactors that are deemed both safer and more economical.[17] To date, however, no firm plans for either constructing a new unit or restarting a mothballed unit have been announced.

Canada

Nuclear power accounted for 14 percent of Canada's electricity generation in 1999, but its share is expected to drop slightly, to 13 percent, by the end of the forecast period. In late 1997 and early 1998, Ontario Power Generation (formerly Ontario Hydro) shut down seven of its older nuclear power plants, or 17 percent (4,300 megawatts) of its operating capacity. Canada still has 14 nuclear power plants currently in operation. In July 2000, Ontario Power Generation announced its planned lease of the operation of eight of its Bruce reactors, four of which were shut down in 1998, to British Energy. In January 2001, Canada's nuclear safety commission scheduled two hearings for licenses to resume operation of three of the closed units. On October 2, 2001, the Canadian Nuclear Power Safety Commission approved an environmental review procedure that is expected to result in the reopening of Ontario's Bruce 3 and 4 nuclear power plants, with a total of 1,500 megawatts of capacity, by 2003 and 2004, respectively [**23**]. In November 2001, the Commission gave provisional approval for the restart of the Pickering A power plant [**24**].

Africa

Among African nations, South Africa is currently the only country with nuclear electricity generation capacity and the only nation expected to produce electricity from nuclear power over the forecast period. South Africa has two 921-megawatt reactors, Koeberg 1 and 2, now in operation, and nuclear power accounted for 7 percent of its electricity generation in 1999. South Africa's state-owned utility, Eskom, has been experimenting with pebble bed modular reactor technology since 1993 and had proposed the construction of a 110-megawatt demonstration reactor beginning in mid-2001, although the most recent phase calls for units in the 120 to 130 megawatt range. In November 2001, the proposed construction start time for the pebble bed modular reactor was delayed for up to 12 months upon completion of a feasibility study [**25**]. The *IEO2002* forecast does not expect the reactor to come online until late in the forecast period.

Eastern European and the Former Soviet Union

Nuclear power capacity in Eastern Europe and the former Soviet Union (EE/FSU) is expected to decline over the forecast period, primarily as a result of the retirement of plants in the FSU that have been the subject of safety concerns. By 2020, the region is expected to have 37,000 megawatts of capacity, compared with 44,000 megawatts in 1999.

The EE/FSU region has 59 reactors operating at 18 nuclear energy sites. Twenty-five are considered to be operating at standards below those acceptable in the West. A major goal of Western efforts has been to shut down the least safe nuclear reactors operating in the EE/FSU countries.

[17] These include the Westinghouse AP600 design, General Electric's Advanced Boiling-Water Reactor, and the Combustion Engineering Systems 80+ model.

In 1992, the International Atomic Energy Agency began a review of safety practices at Soviet-designed RBMK-type reactors. RBMKs are graphite-moderated channel reactors. Six of the 15 RBMK plants currently in operation are "first generation," because they were built in the early to mid-1970s. They are considered less safe than those built later. In total, the Soviets built 17 RBMK units (including the 4 units at Chernobyl), of which 13 are still active. Eleven RBMK reactors are operating in Russia and two in Lithuania, and one is currently under construction.

Lithuania was promised 200 million euros (about $180 million) from the European Commission and twelve other nations in grants to help ease the financial burden of shutting down its RBMK Ignalina 2 nuclear power plant before 2005. Similar efforts are being undertaken to close down Bulgaria's Kozloduy plants and Slovakia's Bohunice plants. Bulgaria intends to close Kozloduy units 1 and 2 in 2002 or 2003. Bulgaria has agreed to close Kozloduy units 1-4 "at the earliest possible date." The European Union (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 . Both Lithuania's and Slovakia's future entry into the EU has been jeopardized by the concerns associated with their nuclear power industries. In December 1995, the Group of Seven and Ukraine reached an agreement to shut down all units at Chernobyl by 2000. The Chernobyl accident in 1986 destroyed unit 4, and unit 2 was shut down in 1991. Under the agreement, unit 1 was shut down in 1996, and Ukraine shut down the last of the four reactors, Chernobyl 3, in December 2000.

In October 2000, the first of the Czech Republic's two Temelin nuclear power reactors was brought online after a long-running dispute with Austria and Germany. Construction on Temelin, which began in 1987, was delayed for financial and technical reasons [***26***]. Unlike the RBMKs discussed above, Temelin is a pressurized-water reactor. Westinghouse was brought in to upgrade the Temelin plant to Western standards.[18] British Energy has indicated a willingness to purchase both the Temelin plant and the Czech Republic's Dukovany reactors, adding to a portfolio of nuclear assets that includes plants in the United States and Canada.

References

1. International Atomic Energy Agency, "Power Reactor Information System," web site www.iaea.org/programmes/a2/ (February 12, 2002).
2. Nuclear Energy Institute, "Up Front: Nuclear Plant Security Quotes," web site www.nei.org (February 12, 2002).
3. BP p.l.c., *BP Statistical Review of World Energy 2001* (London, UK, June 2001), pp. 18 and 28, web site www.bp.com.
4. Energy Information Administration, *Annual Energy Review* (historical data), web site www.eia.doe.gov/emeu/mer/txt/mer10-4a.
5. International Energy Agency, *Nuclear Power in the OECD* (Paris, France, 2001), p. 99.
6. Testimony of Mary J. Hutzler, Energy Information Administration, before the Subcommitte on Energy and Air Quality, Committee on Energy and Commerce, U.S. House of Representatives, Hearing on Nuclear Power (March 27, 2001), web site www.eia.doe.gov/oiaf/speeches/0327eia.html.
7. Nuclear Energy Institute, "Newsroom: Nuclear Industry Data at a Glance: Fuel/Refueling Outages," web site www.nei.org.
8. U.S. Nuclear Regulatory Commission, "Fact Sheet: Power Uprates for Nuclear Plants," web site www.nrc.gov (August 2001).
9. International Energy Agency, *Nuclear Power in the OECD* (Paris, France, 2001), p. 99.
10. Board of Governors of the Federal Reserve System, "Research and Data: Statistics: Releases and Historical Data: Daily Releases H.15, Daily Update, Historical Data, Prime Bank Loan," web site www.federalreserve.gov (updated daily).
11. Energy Information Administration, *Assumptions to the Annual Energy Outlook 2002*, DOE/EIA-0554(2002) (Washington, DC, December 2001), Table 38, p. 68.
12. International Atomic Energy Agency: General Conference, "Nuclear Technology Review—Update 2001," sub-item 17(d) of the provisional agenda, GC(45)INF/5 (August 29, 2001), p. 2.
13. U.S. Department of Energy, Office of Nuclear Energy, Science and Technology, and Nuclear Energy Research Advisory Committee, Subcommittee on Generation IV Technology Planning, *A Roadmap To Deploy New Nuclear Power Plants in the United States by 2010: Volume I, Summary Report* (Washington, DC, October 31, 2001), web site www.ne.doe.gov/nerac/ntdroadmapvolume1.pdf.
14. World Nuclear Association, "Sweden: The Closure of the Barseback-2 Nuclear Plant," News Briefing NB01.17-13 (April 18-24, 2001), web site www.world-nuclear.org/nb/nb01/nb0117.htm.
15. *Nuclear Alert*, *Financial Times* (June 16, 2000), p. 14.
16. "Anniversary Energizes Review of Italy's N-Power Options," *NucNet News*, e-mail edition (October 4, 2001).

[18] Westinghouse is a unit of British Energy.

17. "Use of N-Power Unavoidable for EU Security and Environment," *NucNet News*, e-mail edition (September 25, 2001).

18. "Martin Villa Joins De Palacio To Support Nuclear Energy," *El Pais* (Spain) (February 21, 2002), abstracted on the *Financial Times* web site, www.news.ft.com.

19. R.A. Meserve, "What the National Energy Strategy Means for the Nuclear Power Industry." Speech delivered at the Energy Investor Policy & Regulation Conference (New York, NY, December 4, 2001).

20. U.S. Department of Energy, National Policy Development Group, *National Energy Policy* (Washington, DC, May 2001), p. 5-17.

21. U.S. Department of Energy, Office of Nuclear Energy, Science and Technology, "Solicitation for a Study of Potential Sites for the Deployment of New Nuclear Power Plants in the U.S." (August 23, 2001), web site www.ne.doe.gov/ page.html.

22. "Browns Ferry-1 Likely To Join Units 2. 3 in Relicensing Line," *Nucleonics Week* (January 3, 2002), p. 1.

23. Bruce Power, "Bruce Power Proceeds With Bruce A Restart Environmental Screening," Press Release (October 2, 2001), web site www.brucepower.com/ media.htm.

24. "2001: The Year of the Nuclear Renaissance," *NucNet News*, e-mail edition (December 24, 2001).

25. "Consortium Renews Support for PBMR Project After Feasibility Study," *NucNet News*, e-mail edition (November 6, 2001).

26. L. Bauerova, "Austria Fights Nuclear Plant Near Border in Czech Hills," *The New York Times* (September 24, 2000), p. A7.

Hydroelectricity and Other Renewable Resources

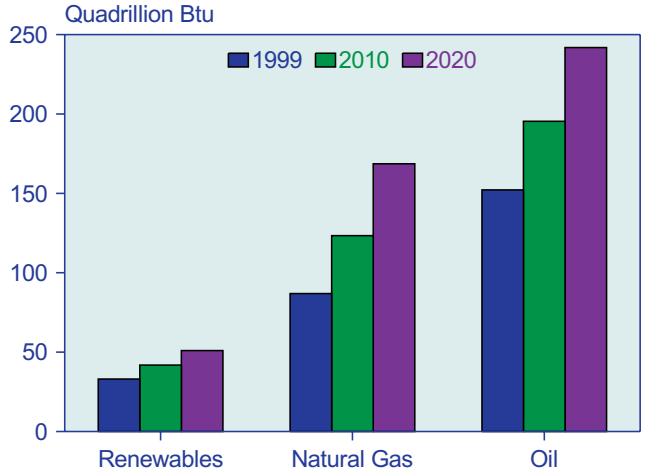
The renewable energy share of total world energy consumption is expected to decline slightly, from 9 percent in 1999 to 8 percent in 2020, despite a projected 53-percent increase in consumption of hydroelectricity and other renewable resources.

The use of hydropower and other renewable energy resources is projected to increase in the *International Energy Outlook 2002* (*IEO2002*) mid-term forecast. From 1999 to 2020, worldwide consumption of renewable energy is projected to increase by 53 percent, as compared with expected increases of 92 percent for natural gas and 58 percent for oil consumption (Figure 67). Growth in demand for renewable energy resources is expected to continue to be constrained by relatively moderate fossil fuel prices.

New, large-scale hydroelectric installations are expected to provide much of the growth in renewable energy use in the developing world. China, India, Malaysia, and other developing Asian countries continue to construct or plan large-scale hydropower projects. Construction on the largest project, China's 18,200-megawatt Three Gorges Dam, continued in 2001 despite reports of corruption and problems in the relocation of populations from the reservoir site. Malaysia continues to work on its 2,400-megawatt Bakun hydroelectric project, although to date only the mile-long underground river diversion tunnel has been completed [***1***].

The heavy reliance on hydroelectric power in many countries of Central and South America has become a burden for some, because drought has endangered the reliable supply of electricity. In Brazil, persistent drought in 2001 led to a substantial decline in reservoir levels and, therefore, the ability of hydroelectric power plants to provide electricity. Brazil's government enforced a 20-percent cut in power use as part of a rationing program, and considered other measures such as reducing the work week, in an effort to avoid blackouts [***2***]. In the fall of 2001, reservoir levels were 28 percent below capacity in key regions of the country. Brazil is responding by increasing the pace of natural-gas-fired power plant construction, a trend that many governments in the region see as necessary in order to diversify electricity supply sources and avoid shortages in the future.

Figure 67. Worldwide Consumption of Renewables, Natural Gas and Oil, 1999, 2010, and 2020



Sources: **1999:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **2010 and 2020:** EIA, World Energy Projection System (2002).

In the industrialized world, Canada is among the only countries with plans to expand large-scale hydroelectric resources, such as the 2,000-megawatt Lower Churchill Project at Gull Island in Newfoundland Province. Many developed countries have already substantially exploited their hydroelectric resources, and increments to their renewable energy consumption are expected to come from wind, solar, and other nonhydroelectric renewable energy sources.

Worldwide, some 3,800 megawatts of new wind energy capacity were installed during 2000, and the American Wind Energy Association estimated that another 5,000 megawatts would be added in 2001 [***3***]. Wind remains the fastest-growing source of renewable energy in the industrialized world. Germany added 1,650 megawatts of wind capacity in 2000, making it the country with the largest annual increment in wind capacity worldwide, as it has been for the past several years. Germany's increase was followed by Spain's 795 megawatts of installed new wind capacity and Denmark's 588 megawatts [***4***]. The European Union (EU) finalized the agreement for a Renewable Directive in September 2001 [***5***]. The directive sets goals of doubling the renewable energy share of total energy consumption in the inland EU to 12 percent by 2010, and increasing the renewable energy share of electricity generation from 14 percent in 2001 to 22 percent by 2010.

New wind capacity additions in the United States decreased sharply in 2000, after a record increment of 565 megawatts in 1999, when the wind energy

production tax credit expired. The credit has since been extended to December 31, 2003, and a similar surge in U.S. wind power additions was expected in 2001. The Energy Information Administration's *Annual Energy Outlook 2002* (*AEO2002*) estimates that 1,872 megawatts of wind capacity was added in the United States in 2001.

The *IEO2002* projections for hydroelectricity and other renewable energy sources include only on-grid renewables. Although noncommercial fuels from plant and animal sources are an important source of energy, particularly in the developing world, 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.

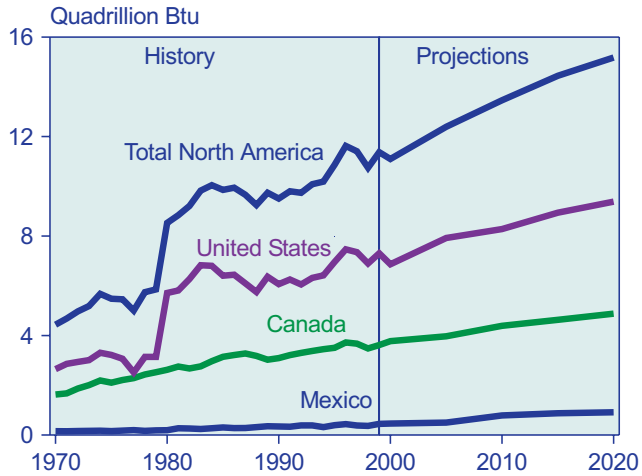
Regional Activity

North America

Hydroelectricity remains the predominant form of renewable energy use in North America, particularly in Canada. In 1999, hydroelectric power provided nearly 60 percent of the Canada's 551 billion kilowatthours of electricity generation [***6***], compared with 8 percent in the United States and 14 percent in Mexico.

In the *IEO2002* reference case forecast, renewable energy use in North America as a whole is projected to increase by 1.4 percent per year between 1999 and 2020 (Figure 68). Although Canada has announced some plans to expand its hydroelectric capacity over the next decade, hydropower consumption is expected to remain flat or decline slightly over the projection period for the region. Increases are expected for geothermal, wind, solar, biomass, and municipal solid waste (MSW) energy use.

Figure 68. Renewable Energy Consumption in North America, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

United States

Potential sites for hydroelectric dams have already been largely established in the United States, and environmental concerns are expected to prevent the development of any new sites in the future. EIA's *AEO2002* projects that U.S. conventional hydroelectric generation will decline from 316 billion kilowatthours in 1999 to 304 billion kilowatthours in 2020 as increasing environmental and other competing needs reduce the productivity of generation from existing hydroelectric capacity [***7***].

Nonhydroelectric renewables are expected to account for 3.9 percent of all projected additions to U.S. generating capacity between 2000 and 2020. Generation from geothermal, biomass, landfill gas, solar, and wind energy is projected to increase from 77 billion kilowatthours in 1999 to 160 billion kilowatthours in 2020. Biomass (which includes cogeneration and co-firing in coal-fired power plants) is expected to grow from 38 billion kilowatthours in 2000 to 64 billion kilowatthours in 2020. 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. High-output geothermal capacity could increase by 87 percent over the next two decades, to 5,300 megawatts, and could provide almost 35 billion kilowatthours of electricity generation by 2020. This will depend, however, on the success of several new, untested sites. Wind capacity in the United States is projected to grow by nearly 300 percent over the forecast period, from 2,400 megawatts in 2000 to 4,300 megawatts in 2001 and 9,100 megawatts by 2020. Wind capacity was installed or under construction in 28 States by the end of 2001 (Figure 69), 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. State mandates are expected to have the greatest impacts on renewable capacity additions in Texas (2,279 megawatts), California (1,930 megawatts), Nevada (1,148 megawatts), and New Jersey (904 megawatts), and smaller increases are expected in Massachusetts, Minnesota, Iowa, Wisconsin, and Arizona.

Canada

At present, 60 percent of Canada's total installed electricity generation capacity consists of hydroelectric dams [***8***]. Canada is exploring ways to increase its hydroelectric capacity still further with several proposals that are currently under consideration. In the

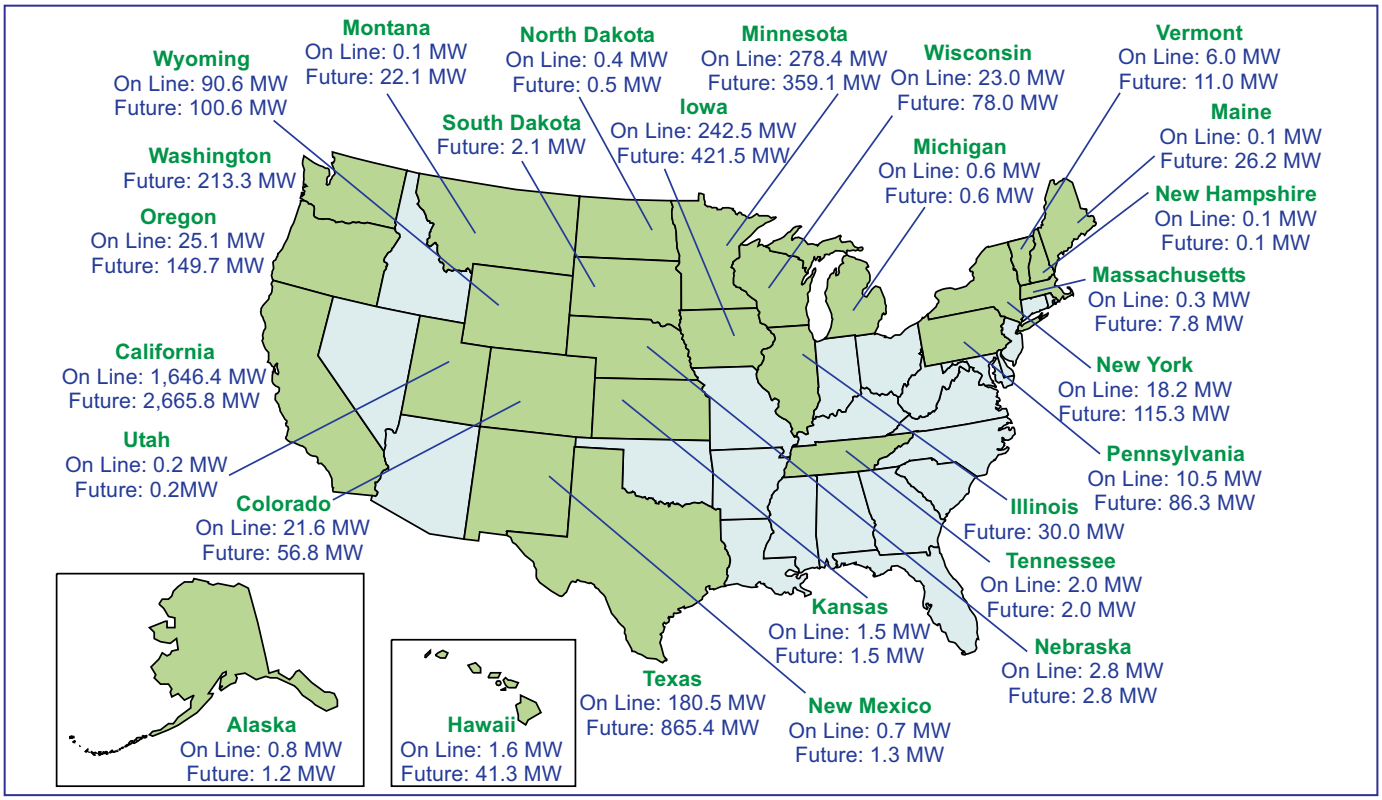
Northwest Territories there are proposals to develop hydroelectric projects that would total between 12,000 and 15,000 megawatts [**9**]. The projects would cost an estimated $17.5 billion and would be constructed in a sparsely populated part of the country on six separate rivers: the Mackenzie, Bear, Lockhart, Talston, Snare, and Lac la Marte. The government has identified 10,000 megawatts of potential development that could be exploited by developing sites on the Mackenzie River. The largest site on the Mackenzie, Ramparts, has a potential for 4,500 megawatts. Estimates are that the projects would take between 5 and 20 years to complete.

The successful development of these projects, as well as many others in Canada will depend on agreements with the local populations that will be displaced or otherwise affected by the projects. In the past, local concerns were not always taken into consideration, and Canadian aboriginal groups began to fight further developments through legal means, often successfully suing developers for reparations or to scale down proposed projects. The current trend is for governments and companies to work with the aboriginal tribes to reach consensus before construction begins, including offers of joint ownership and extensive environmental impact studies. The government of the Northwest Territories is meeting with the indigenous groups that would be affected by hydroelectric development and must reach an agreement with them before any construction begins.

One successful outcome of the new government strategy to gain approval for development from the indigenous people who will be affected by the construction of new hydroelectric infrastructure is the 1,200-megawatt Eastmain Rupert project [**10**]. In 2000, the provincial utility Hydro-Quebec paid the Grand Council of the Crees some $300,000 to conduct a 3-month study of the economic, commercial, and environmental aspects of the utility's proposal to construct the hydroelectric project. The project will cost an estimated $2.5 billion to construct and will involve the diversion of the Rupert River in the James Bay region of Quebec. Although an agreement has been reached between Quebec and the Crees, feasibility studies and environmental authorizations remain to be completed and are expected to take nearly 4 years. If all approvals are obtained, construction could be completed in 2011.

There are still other plans to construct large-scale hydroelectric projects in Canada. The governments of Newfoundland and Quebec provinces have proposed construction of a 2,000 megawatt Lower Churchill Project at Newfoundland's Gull Island. The project has been scaled back from 2,800 megawatts, because Newfoundland determined that it would be too expensive to construct a phase of the project that involved building an 800-megawatt powerhouse at Muskrat Falls. The government of Newfoundland is working with U.S. company Alcoa on a study of the Lower Churchill River on

Figure 69. Grid-Connected Wind Power Plants in the United States as of December 31, 2000



Source: National Renewable Energy Laboratory, *IEA Wind Energy Annual Report 2000* (Golden, CO, May 2001), p. 186.

Labrador that will determine the feasibility of constructing hydroelectric facilities at Gull Island and Muskrat Falls to support proposed aluminum smelters in Newfoundland and Labrador [***11***].

Quebec's government has also approved a plan by Hydro-Quebec for construction of a dam and 526-megawatt powerhouse on the Toulnustouc River, on the north shore of the St. Lawrence River about 60 miles north of Baie-Comeau [***12***]. The project's powerhouse is part of a larger project supported by the Betsiamites Innu-Montagnais aborigines that would include several river diversions. Authorization has not yet been obtained for some parts of the larger project. Construction of the 526-megawatt powerhouse that has been approved will take an estimated $400 million and will involve enlarging Lake Sainte-Anne reservoir, building a dam and a powerhouse, and connecting the powerhouse to the Micoua substation. Construction will not begin until the project has been approved by the Canadian federal government.

Hydro-Quebec has a number of plans for additional mid-size hydro power projects over the next decade. Quebec's government has authorized Hydro-Quebec to begin a draft design study for a dam and 220-megawatt powerhouse on the Romaine River near Havre-Saint-Pierre. If approved, construction of the $335 million La Romaine Project could begin in 2004. The station could be commissioned in 2007, generating 1,000 gigawatt-hours annually. Another technical and environmental study has been launched for the development of a 450-megawatt hydroelectric plant on the Peribonka River nearly 200 miles north of Quebec City [***13***]. The project would generate an average 2,200 gigawatthours of electricity annually. If all goes according to plan, the studies will be completed by mid-2003, with construction beginning in 2004 and commissioning set for 2009.

Along with mid- to large-scale hydro projects, Canada is showing increasing interest in smaller scale hydroelectricity and alternative renewable energy sources, such as wind, that have not previously been exploited in the country. The Canadian Renewable Energy Corporation announced in September 2001 that it would evaluate nearly a dozen potential sites for small, run-of-river hydroelectric development in Ontario [***14***]. The company plans to install 38 megawatts of new renewable capacity within the next 3 years, beginning with the 3-megawatt Misema power project on the Misema River in eastern Ontario. Construction on Misema began in 2001 and is scheduled for completion in November 2002 [***15***].

Another example of the development of smaller scale hydroelectric facilities is the construction of the Granite Canal hydroelectric project on Newfoundland Island. Construction on the 40-megawatt site began in May 2001. The project is being built by Newfoundland & Labrador Hydro company and should be operating by 2003 [***16***].

At the end of 2000, there was an estimated 137 megawatts of total installed wind capacity in Canada [***17***]. At present, the provinces of Quebec and Alberta have the largest shares of Canada's wind capacity. There are, however, new government incentives to increase wind power projects throughout the country and as a result several projects are expected to become operational over the next year. In December 2001, Canada implemented a wind power production incentive. Wind projects installed between April 1, 2002, and March 31, 2007, will be eligible for a government incentive payment of about 0.8 cents per kilowatthour of generation [***18***]. The payment will gradually decline to 0.5 cents per kilowatthour.

In Saskatchewan's Gull Lake, the first phase of the $12.8 million SunBridge Wind Power Project has begun generating electricity [***19***]. Three of the 17 wind turbines began generating in August 2001, and the remaining turbines should be operational by June 2002, when total installed capacity should reach 11.2 megawatts. The Canadian government has agreed to purchase electricity from emerging renewable sources in Saskatchewan and Prince Edward Island, and for the Gull Lake wind project this will mean an investment of around $7.9 million over a 10-year period [***20***]. Power from the project will be fed into the provincial power grid and used to supply electricity to federal government buildings in Saskatchewan, among other customers.

In June 2001, the Canadian government, the Prince Edward Island provincial government, and Maritime Electric Company, Ltd. announced that an agreement had been signed for the development of a wind farm at North Cape to be constructed by the Prince Edward Island Energy Corporation [***21***]. The project, which is expected to cost $5.9 million, will generate an estimated 16.6 million kilowatthours of electricity annually.

In August 2001, Ontario Power Generation commissioned North American's largest wind turbine at the Pickering Nuclear Generating Station [***22***]. The 1.8-megawatt turbine is supposed to generate enough energy to supply 600 average Canadian homes. The company is also planning a 10-megawatt wind farm near Lake Huron, which is scheduled for completion by summer 2002. Ontario Power Generation has committed to increasing its total renewable generating capacity to 500 megawatts by 2005, from a present 138 megawatts.

Mexico

In Mexico there are limited plans to expand the renewable energy resource base at the present time. Mexico has made some moves toward increasing the

development of geothermal resources, including studies by the state-owned Comisión Federal de Electricidad (CFE) [*23*] and a government pledge to invest some $31 million in geothermal energy. There has been little activity in wind power development in Mexico, although by some estimates Mexico has wind resources that could support the installation of up to 5,000 megawatts of wind power capacity [*24*]. The country has about 3 megawatts of installed wind capacity but has not added any new capacity since 1998. Construction of a 54-megawatt wind power project proposed by CFE in 1996 has continued to be postponed. In addition, five other wind projects proposed by private companies are still being negotiated. Construction permits have been issued to four of the five projects, but no construction work has been started.

Western Europe

Expansion of renewable energy sources in Western Europe is expected to be mostly in the form of nonhydroelectric renewables. Most potential hydroelectric resources have already been developed in the region, and there are few plans to extend hydropower capacity over the next two decades. Among the other forms of renewable energy, wind has made the greatest gains over recent years and will probably contribute to much of the future growth in renewable energy use.

The EU has moved to increase the penetration of renewables in the European energy mix. In 2001, the European Parliament approved a Renewables Directive that would require the EU to double the renewable share of total energy consumption by 2010 [*25*]. According to the new law, the share of total inland energy consumption met by renewable energy resources will have to increase to 12 percent in 2010, from an estimated current level of about 6 percent. Furthermore, the share of electricity demand met by renewables will have to increase to 22 percent, from about 14 percent now.

Individual European countries have been implementing various strategies to increase their use of renewables. The United Kingdom has introduced a "renewables obligation," which will require electricity suppliers to derive 3 percent of their electricity from renewable resources beginning in 2002, rising to 10 percent in 2011. Germany's Gesetz für den Vorrang Erneuerbarer Energien law was enacted on April 1, 2000; it requires that electricity grid operators give "priority access to all renewable energy" and sets fixed rates for each renewable (the cost is passed to the consumer) [*26*]. France has also set rates for renewable energy in the wholesale market to ensure that a planned installation of 10,000 megawatts of wind power occurs by 2010 [*27*].

In contrast to the German and French strategies of ratesetting, the government of the Netherlands uses "green certificates" to create a market for renewables. Generators are given green certificates for their renewable power production that provide tax credits and can be traded. The resulting tax savings or the earnings made from the sale of the certificates are supposed to allow renewable generators to sell more of their power in the market. In the past, Denmark has required utilities to allow private renewable energy producers access to the grid and has required utilities to pay the producers a percentage of their production and distribution costs. Now the Danish government is also introducing renewable energy certificates, similar to the Dutch scheme.

Of all the renewable energy sources, wind is the most promising in Europe. Germany, Spain, and Denmark have been among the world's top wind capacity installers in recent years, and in 2000 Italy and the United Kingdom also saw sharp increases in wind power capacity installations.

In 2000, Germany expanded its total installed capacity by 1,668 megawatts, bringing its combined operating wind capacity to 6,113 megawatts. In August 2001, Europe's largest onshore wind farm, the 105-megawatt Sintfeld wind farm, began production near Paderborn, Germany [*28*]. The project is expected to provide enough electricity for 70,000 homes.

Denmark added 588 megawatts of wind capacity in 2000, twice as much new capacity as it has installed in recent years [*29*]. The country has one of the most mature wind power markets in the world and currently meets an estimated 12 percent of its total electricity demand with wind energy. Under the government's Energy 21 strategy, the national target is to have 1,500 megawatts of wind power installed by 2005 and 5,500 megawatts by 2030. The 2005 target has already been exceeded; however, most of the potential on-land sites available for wind facilities have already been exploited, and 4,000 of the 5,500 megawatts that must be in place by 2030 are supposed to be offshore (see box on page 110). Thus far, Denmark has only 50 megawatts of offshore installed wind capacity.

Like Germany and Denmark, Spain has seen substantial growth in wind power capacity over the past several years. In 2000, it added 795 megawatts of wind capacity, bringing the country's total installed wind generation capacity to 2,334 megawatts, nearly the level of the mature wind market in Denmark. The government encourages the development of renewable generation by offering producers a choice of incentives. Either the producer can opt to be paid a fixed price for the electricity it produces (the price varies by renewable energy source), or it can accept a variable price based on the average price of the market pool, plus a bonus based on the amount produced.

Development of Offshore Wind Power in Denmark

Over the past decade, wind power has moved from being a novel, unconventional technology to achieving significant, and in some cases substantial, market penetration. In many industrialized countries, governments and environmental planners view wind energy as a low-cost pathway to achieving substantial reductions in greenhouse gas emissions and addressing other environmental problems associated with conventional generation technologies. To achieve these goals, many countries have started to look beyond conventional land-based wind turbine technology, with its economic and physical limitations, and have set their sights on the windy expanses of coastal oceans and seas surrounding northwestern Europe.

The Danish government has set substantial targets for growth in wind-powered electricity generation and expects it to account for 50 percent of domestic generation by 2030. In the country's Energy 21 plan, a target for installed wind capacity of 5,500 megawatts has been set, of which 4,000 megawatts is to be offshore.[a] This means that, with wind energy currently at about 12 percent of electricity demand, much of the remaining land-based wind resource in Denmark is believed to be unsuited for development. Limitations include:

- Poor remaining resources: Denmark has never been rich in high-quality wind resources, and most of the suitable land resource is already utilized.[b]
- Competing land uses: Denmark is a densely populated country, with correspondingly high land costs.
- Landscape impacts: Although the Danish people seem largely to have shared in their government's commitment to wind power, there is some evidence of growing resistance to further visual intrusion by the increasingly tall wind turbines in rural areas.[c]

Denmark already has several pilot-scale offshore wind facilities and in 2000 commissioned what is, for now, the largest commercial offshore operation, a 20-turbine, 40-megawatt facility on the Middelgrunden shoal off of Copenhagen. Other recent European installations include a 10-megawatt facility near Blyth, England, and another 10-megawatt facility on the Utgrunden shoal in Swedish waters.

There are substantial additional costs associated with the offshore development of wind resources, and it might be asked, "Why build offshore at all?" For much of northwestern Europe, the answer is simple: that's where the wind is. Denmark has been an early adopter of wind energy, and its industry remains the global leader in the field. Not surprisingly, much of the early offshore development has occurred in Danish waters as suitable unused land sites in the country have become increasingly scarce. Although Germany has significant inland resources, many other countries, such as the United Kingdom, the Netherlands, and Belgium, find themselves with few easily developed land sites but ample coastlines.

Although concepts for offshore wind power have existed longer than there has been a commercial wind industry, realization of those visions had to wait for both the technology and the economic necessity to catch up. Enabling technologies have come, naturally, from the wind industry itself and have also benefited from the engineering expertise of the offshore oil industry. Even with technological advances, however, offshore wind power remains substantially more expensive than land-based wind power in good resource areas. As economically viable wind power opportunities on land are exhausted, offshore wind becomes an increasingly attractive proposition.

A key enabling technology for offshore wind is the turbine foundation.[d] Foundation design and engineering concepts are based on offshore oil rig foundations. Unlike land-based foundations, offshore wind turbines face additional loading from wave action, sea-bed scouring, and (in northern climates) pack ice. Oil rig designs, made for largely static above-water loads, must be modified to face the additional dynamic loading imposed by the turbine itself. Additionally, while oil rig technology has progressed to ever-deeper waters, wind turbines will likely be limited, at least in the near term, to waters near shore with smaller critical wave heights, shorter distances to lay power transmission cables, and closer maintenance facilities.[e] Of course, placement of turbines too close to shore will start to limit the offshore benefits, including

(continued on page 111)

[a]International Energy Agency and National Renewable Energy Laboratory, *IEA Wind Energy Annual 2000* (Golden, CO, May 2001), p. 69.

[b]The *IEA Wind Energy Annual 2000*, p. 69, indicates that in 2000 approximately 2,300 megawatts of onshore capacity was installed, with a "realistic" maximum capacity of about 2,600 megawatts.

[c]J. Samuelsberg, "Analysis—Offshore Wind Power Swirls Through Europe," web site www.climateark.org/articles/2000/2nd/offswind.htm (April 13, 2000). See also web site http://rotor.fb12.tu-berlin.de/windfarm/offshore.vindeby.html.

[d]See various topics in *OWEN Workshop on Structure and Foundation Design of Offshore Wind Installations* (Offshore Wind Energy Network, March 2000), web site www.owen.eru.rl.ac.uk/workshop_3/ws3_final.pdf.

[e]B. Standing, "Wave and Current Characterization Modeling," *OWEN Workshop on Structure and Foundation Design of Offshore Wind Installations* (Offshore Wind Energy Network, March 2000), web site www.owen.eru.rl.ac.uk/workshop_3/ws3_final.pdf.

Development of Offshore Wind Power in Denmark (Continued)

low-turbulence winds found over the relatively smooth ocean surfaces and less visibility from populated areas.

Because a major additional expense of offshore turbines compared to land-based turbines is in the foundation construction, the key development in turbine technology has been larger turbines. With larger turbines (2- to 5-megawatt turbines are currently under development for the offshore market, compared with 1 to 2 megawatts for onshore installations), fewer foundations have to be constructed to achieve comparable output, which reduces overall construction costs. Although the offshore foundations will be exposed to much rougher conditions from ocean waves than are land-based foundations, which are essentially static, the turbines themselves should encounter less turbulent winds (because the surface of the sea is not as rough as the trees, hills, and mountains on land) and may benefit from higher blade-tip speeds (because there is less concern over noise pollution from offshore turbines than there is for land-based turbines).

Some believe that reduced wind turbulence will increase the life of offshore turbines relative to land-based turbines; however, additional operations and maintenance expenses will also be incurred, resulting from the additional costs of transporting personnel to the facility and protecting against corrosion in the salt-water environments.[f] The industry, still not mature, is effectively still building "first-of-a-kind" commercial units; but early indications show a 50- to 100-percent capital cost penalty compared to land-based units ($1,500 to $2,000 per kilowatt of capacity for offshore, around $1,000 for land-based),[g] as well as a significant maintenance penalty (also in the range of 50 to 100 percent, although the numbers are less reliable).

Over the past 15 years, the Danish government has encouraged the growth of a vibrant domestic wind power industry through "grassroots" development. Individual farmers, or small farmer cooperatives, have been given incentives to develop small wind clusters on their lands, and the utilities in turn have been required to accommodate this new power source on the distribution grid. In the early years of the developing Danish wind industry, regulations required local ownership and consumption of wind power.[h] Tax breaks and direct subsidies have also played an important role in spurring new installations.[i] Finally, Danish utilities are required not only to connect wind turbines to the distribution grid but also to upgrade distribution facilities where required to accommodate the resources.[j]

To achieve their ambitious 2030 wind generation target, the Danes have, in some cases, turned to the American model of large "wind farms" of hundreds of megawatts of capacity built, owned, and operated by a utility or corporate third party.[k] The Danes have recognized that development on the scale envisioned will inevitably require them to look to the ocean as an alternative to increasingly low-quality, high-cost, and unattractive resources onshore. Such development will not likely result from the grassroots efforts of independent farmers, but will require the capital and technological resources of established wind turbine manufacturers, developers, and utilities.

In much of the rest of Western Europe, offshore wind is also seen as an attractive generation technology, for much the same reasons: a political commitment to greenhouse gas reduction, limited land-based wind resources, high population density, and negative public reaction to the tall wind towers. In addition, Western Europe has a relatively shallow continental shelf, allowing placement of wind turbines farther offshore without encountering water that is too deep. As a result, the mid-term outlook for offshore wind seems largely focused on ocean shallows surrounding Western Europe.

[f]G. Siefert, "5 Years of Ascension Island Wind Farm Operations," *WindPower 2001 Conference Proceedings* (June 2001).

[g]See, for example, web sites http://rotor.fb12.tu-berlin.de/windfarm/offshore.vindeby.html and www.windpower.dk/tour/econ/offshore.htm.

[h]F. Tranaes, "Danish Wind Energy Cooperatives" (Danish Wind Industry Association, 1997), web site www.windpower.dk/articles/coop2.htm.

[i]International Energy Agency and National Renewable Energy Laboratory, *IEA Wind Energy Annual 2000* (Golden, CO, May 2001), p. 70.

[j]F. Tranaes, "Danish Wind Energy Cooperatives" (Danish Wind Industry Association, 1997), web site www.windpower.dk/articles/coop2.htm.

[k]International Energy Agency and National Renewable Energy Laboratory, *IEA Wind Energy Annual 2000* (Golden, CO, May 2001), p. 72.

Even some European countries that have been slow in developing wind programs heretofore are beginning to make plans for expanding this renewable energy source. Offshore wind is allowing European countries that do not have the land area to devote to wind turbines a chance to begin exploiting wind energy. TotalFinaElf plans to build a large wind farm off the coast of Belgium [***30***]. The company is currently seeking a license from the Belgian Electricity and Gas Regulatory Commission to construct and operate the wind farm. The project would consist of 40 wind turbines installed at a distance of 5 to 10 miles from shore. Upon completion, the facility would have a combined capacity of 100 megawatts, which TotalFinaElf estimates would provide enough power to supply some 150,000 households.

The United Kingdom experienced a jump in wind installations in 2000, after many years of lackluster activity. Ten projects with a combined capacity of 63 megawatts were completed in 2000. The greatest obstacle to new growth in the country's wind capacity remains the difficulty developers have in obtaining planning approvals. In 2001, ScottishPower announced plans to construct what will be the United Kingdom's largest wind farm at Eaglesham Moor south of Glasgow [***31***]. The $213.8 million project will consist of 140 turbines and will have a combined capacity of 240 megawatts. The project could be completed by 2003; however, ScottishPower has yet to obtain the necessary regulatory approval.

There are also some plans to expand solar power in Western Europe. In anticipation of future growth in solar energy, BP Solar committed to constructing Europe's largest solar equipment manufacturing plant in Spain in 2001 [***32***]. The plant will be able to produce 60 megawatts per year of high-efficiency solar cells (with an aim to expand that amount to 100 megawatts). BP plans to invest $101.7 million to expand existing facilities in the plant to be located north of Madrid. The project should be complete by 2002 [***33***].

Industrialized Asia

The countries of industrialized Asia (Australia, Japan, and New Zealand) have markedly different electricity energy mixes. Japan is the only one of the three countries with a nuclear generation program, supplying one-third of its electricity from nuclear power plants. Hydroelectricity and other renewable energy sources supply about 12 percent of Japan's electricity. Renewables also account for about 10 percent of Australia's electricity supply, and thermal generation (predominantly coal) accounts for nearly 90 percent. In contrast, renewable energy sources provide 73 percent of New Zealand's electricity supply.

Between 1999 and 2020, the use of hydroelectricity and other renewables is projected to increase by 1.4 percent per year in the region of Australasia (which includes Australia and New Zealand, along with the U.S. Territories). Much of this modest increase is expected to be in the form of nonhydroelectric renewables, most notably wind.

Australia

On December 21, 2000, the Australian government passed the Renewable Energy (Electricity) Act 2000 in an effort to encourage renewable energy development [***34***]. The legislation, enacted on April 1, 2001, sets mandatory targets for renewable energy. It requires wholesale purchasers of electricity to contribute to the generation of an additional 9,500 gigawatthours of renewable energy each year by 2010. Interim targets are to be enforced, and penalties are to be assessed against electricity purchasers who do not attain their individual targets.

The Renewable Energy (Electricity) Act 2000 already appears to be having an impact on renewable energy markets in Australia. The country added 20 megawatts of its total installed wind capacity of 33 megawatts in 2000 alone. Several wind farms are either in the planning stage or currently under construction. The government has estimated that another 300 megawatts of wind capacity is expected to be operational by the end of 2002 [***35***]. In July 2001, the first wind power project in Victoria (and the largest to date in Australia) came online near Warmambool [***36***]. The 18.3-megawatt Codrington project cost an estimated $15 million to construct. Pacific Hydro, which built and operates the project, is completing environmental impact statements for another four wind farms to be located in the Portland region. The company plans to complete construction of the combined 150 megawatts of new wind capacity before the end of 2002.

The 21-megawatt Toora wind farm is currently under construction in Victoria's South Gippland region. Upon completion, its electricity generation is to be sold to CitiPower, an electricity retailer. Queensland's state-owned Stanwell Corporation plans to install 450 megawatts of wind capacity before 2006 [***37***]. Stanwell is looking to expand at a number of sites in South Australia, Western Australia, New South Wales, and Queensland.

Japan

Japan's wind energy development also increased sharply in 2000, when 50 megawatts of wind capacity was installed, bringing total installed capacity to 121 megawatts [***38***]. Tomen Corporation, a wind energy developer, is investing some $64 million in a 32-megawatt wind plant. Two sites are also planned for the northern part of the country, with installed capacities of 25 megawatts and 15 megawatts.

Some effort has also been made to expand Japan's micro-hydroelectric capacity. In September 2001, Japan's Ministry of Economy, Trade, and Industry

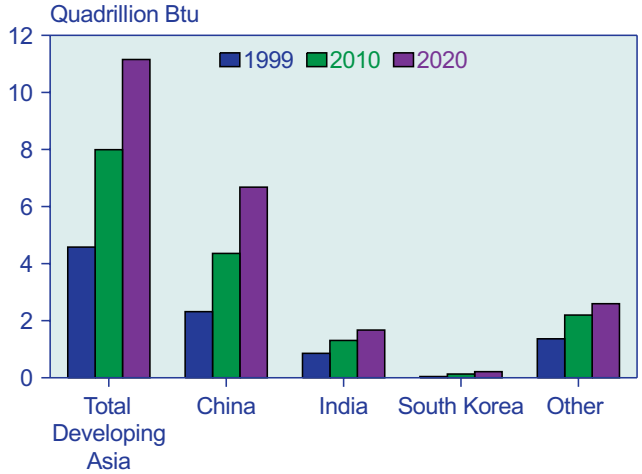
(METI) approved plans to build three new small hydroelectric projects, with a combined generation of capacity of 14.2 megawatts [***39***]. The projects are Chugoku Electric Power Company's 11-megawatt plant in western Japan, Kyushu Electric Power Company's 0.5-megawatt plant on the western island of Kyushu, and the Electric Power Development Company's 2.7-megawatt project in northern Japan. All three plants are scheduled to come online before 2004.

In 2001, the Electric Power Development Company canceled plans to build a large-scale pumped storage hydroelectric station in northern Japan because of the lack of growth in electric power demand. The electricity wholesaler had planned to construct four 450-megawatt generators, with a total capacity of 1,800 megawatts, at Ynotani, Niigata Prefecture, for a total cost of around $3 billion. The projects were supposed to come online in 2011 and 2012, but Tokyo Electric Power Company and Tohoku Electric Power Company requested the delay because electricity demand for 2011 is now expected to lag far behind the forecast made 4 years ago.

Developing Asia

Support for the construction of large-scale hydroelectric dams remains strong in many countries of developing Asia, and large-scale hydropower projects in China, India, Malaysia, and Vietnam, among others in the region, are expected to provide most of the 4.3-percent annual growth in renewable energy consumption worldwide in the *IEO2002* reference case forecast (Figure 70). There are more modest efforts to increase nonhydroelectric renewable energy use, primarily wind and solar, in China, India, and other developing Asian countries, as well as generation from biomass in Bangladesh (see box on page 114). The projects are often aimed at reaching small, rural communities that would otherwise not have access to electricity through the national grid.

Figure 70. Renewable Energy Consumption in Developing Asia, 1999, 2010, and 2020



Sources: **1999:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **2010 and 2020:** EIA, World Energy Projection System (2002).

China

In China, work progresses more or less on schedule on the 18,200-megawatt Three Gorges Dam project, the largest hydroelectric project in the world. The dam is being built on China's Yangtze River. It is scheduled to begin producing electricity in 2003 and to be fully operational by 2009. The Three Gorges Dam project has encountered problems with accusations of corruption, and there have been difficulties in relocating the estimated 1.13 million residents who will have to move before the dam's reservoir can be flooded. Since 1993, more than 350,000 residents have been relocated [***40***].

The Chinese government has also announced that work will begin on another large-scale dam on the Hongshui River in Guangxi Province [***41***]. The Longtan hydroelectric project has a proposed capacity of 5,400 megawatts and is scheduled to begin generating electricity in 2007, with completion by 2009. The project will cost an estimated $3.2 billion. Upon completion, Longtan will be the second largest hydroelectric project in Asia, exceeded in size only by Three Gorges Dam.

Beyond the expansion of large-scale hydropower, several other projects are underway to develop China's other renewable resources, notably, wind and solar. The Global Environment Facility (GEF) and the World Bank have begun a 10-year project to increase China's nonconventional renewable energy use by 14,300 megawatts by 2010 [***42***]. The goal of the China Renewable Energy Scale-Up Program (CRESP) is to begin to reduce China's dependence on coal-fired electricity, as well as to bring electrification to the remote, rural parts of China that do not have access to the national grid. The project is expected to cost billions of dollars. Thus far, the World Bank has committed $100 million in a series of loans that give the country flexibility on meeting deadlines and targets. Another $80 million in the first phase is to come from other donors and the Chinese government, along with $190 million throughout the program's duration. The public investments are expected to encourage up to $212 million in private investments in the first phase and as much as $10 billion in indirect investments over the 10-year period.

One example of the donors that are being attracted to China because of the CRESP is the Asia Development Bank donation of $58 million in 2000 for wind power development, in support of the World Bank project [***43***]. The loan is being used to construct three 26-megawatt wind farms in China. Shell Renewables has also

Biomass Resource Utilization in Bangladesh

On many levels, Bangladesh is a country that is ideally suited for the development of small-scale biomass energy systems. Because the economy is largely dependent on agriculture, the residues needed for such projects are available. Approximately 75 percent of the 130 million people in the country live in rural areas, and for all practical purposes they are not able to benefit from the national electricity transmission grid. The country is relatively poor, with a per capita annual income of $266 (1997 U.S. dollars), as compared with $493 per person in neighboring India. As a result, it is difficult to attract the investment needed to expand the national energy infrastructure.

The lack of infrastructure in Bangladesh's rural areas has resulted in an increase in the migration of rural populations to the country's urban areas, putting enormous pressure on urban infrastructures that are ill-equipped to deal with the influx. As a result, the Bangladeshi government is interested in finding economical ways to bring electricity to the rural areas, both to improve economic development and to stem the migratory trend. Small-scale renewable energy systems fueled by biomass may offer Bangladesh a way to accomplish these goals.

The technologies that have been most popular in terms of development are biogas digesters running on animal or human wastes; turning agricultural wastes into solid fuel briquettes (similar to charcoal); and direct combustion of agricultural waste for household cooking. The main need for energy in rural Bangladesh is for cooking, although biomass is also used as housing material and animal feed. A limited amount of biomass is used as feedstock for recycled paper and in pulp mills. Sources of biomass include rice husks, jute stalks, sugarcane stalks, and peanut shells.

The patterns of biomass usage in developing countries such as Bangladesh could not be more different from those in industrialized countries such as the United States. In industrialized countries there is an abundance of waste biomass material that has only been used once and is contained in landfills, forests, or agricultural lands. A waste stream that may be attractive in the United States, such as municipal solid waste, is fraught with problems in developing countries. In the United States, wastes are carefully entombed in landfills and generally left undisturbed. In developing countries, entire communities of rag pickers, perhaps for several generations, live on and alongside the dumps and earn their living by scavenging materials and selling them to small industries that turn them into a myriad of products ranging from combs to shoes to paper. Consequently, attempts to divert streams of municipal solid waste in developing countries can affect entire classes of people and the small industries that depend on them. Although large quantities of "waste" are generated in a country like Bangladesh due to the agricultural nature of the economy, relatively little of that biomass may be available for use in energy generation. As long as competing uses of biomass material fetch a higher price, or are easier to accomplish, the material will find use in non-energy applications. Two examples illustrate the opportunities and pitfalls for biomass commercialization in a developing country like Bangladesh.

A thriving business in Bangladesh is biomass briquetting or "densification." Briquetting processes require heat and pressure to produce fuel pellets from rice husks and wood chips. There are approximately 900 briquetting machines in operation in Bangladesh, the overwhelming majority of which are locally manufactured. Their capital cost is about $1,080 to $1,180, equipment costs are $500 to $670, land costs are about $360, and installation costs are about $150.[a] Production costs range from $0.78 to $0.93 per pound, and the briquettes can be sold for about $1.04 per pound. The machines produce briquettes at the rate of about 180 pounds per hour and have payback periods of 7.5 months to 18 months.

Briquettes have become popular as a fuel for heating urban hotels and tea shops. In addition, briquettes are in demand as a fuel for melting bitumen, which is used in road paving operations. Brick manufacturing industries can also use the briquettes as a fuel in their ovens. Overall, the prospects for growth of this industry in Bangladesh appear to be bright.

Another example of biomass use in Bangladesh is biodigesters. Unlike briquetting, biodigesters have a mixed record of success. In Faridpur District, a school with about 350 students and 50 staff members uses a biodigester to generate a methane-based cooking fuel.[b] Sludge from the digester is used for fertilizer. The replacement cost for a plant of this type is estimated to range from $515 to $825. The Government of

(continued on page 115)

[a]Institute of Appropriate Technology, *Proceedings of Workshop on Reverse Engineering* (Bangladesh University of Engineering and Technology, Dhaka, Bangladesh, May 2001). Assuming an exchange rate of 70 Taka for 1 U.S. dollar.

[b]A. Jimenez and T. Lawand, *Renewable Energy for Rural Schools* (Golden, CO: National Renewable Energy Laboratory, November 2000).

committed to supply solar power systems to 78,000 homes before 2006 [***44***]. Shell signed an agreement with Sun Oasis Company in Beijing to supply the systems (to be installed and maintained by Sun Oasis) in the western China Autonomous Region of Xinjiang.

India

The Indian government continues to pursue large-scale hydroelectric power, although the projects frequently face difficulties in obtaining financing, as well as protests from environmental and human rights activists. The Narmada Valley Development Project has been planned to include up to 30 large dams, in addition to numerous medium and small ones [***45***]. The 1,450-megawatt Sardar Sarovar hydroelectric project is only one of the large-scale dams to be constructed as part of the Narmada Valley plan.

In October 2000, India's Supreme Court dismissed a petition filed by the Narmada Bachao Andolan (NBA) movement to stop completion of Sardar Sarovar. Work on the project was halted in 1995 when the NBA filed the suit. NBA argued that the dam developers had not made adequate plans for relocating hundreds of thousands of people who would be displaced by the project. The court did rule that the dam may only be constructed to a height of 295 feet, although developers had planned for a height of 453 feet. For every 16-foot height addition beyond the 295 feet, the developers are required to obtain additional planning permission, including the approval of the environmental subgroup of the environment and forestry ministry. In August 2001, the developers gained permission to raise the height of Sardar Sarovar to 328 feet [***46***]. Upon completion, Sardar Sarovar will provide power to Madhya Pradesh and will offer irrigation and food production benefits to Gujarat, Rajasthan, and other arid areas along the north and south banks of the Narmada River, some 600 miles south of New Delhi. In August 2001, project managers announced that Rajasthan should begin receiving its share of water from Sardar Sarovar by June 2004.

India continues to encourage the development of renewable energy sources beyond hydroelectricity. In 2002, Indian Prime Minister Atal Bihari Vajpayee stated he would like renewable energy to account for at least 10,000 megawatts of the 100,000 megawatts of new electricity capacity to be added between 2001 and 2012 [***47***]. The renewable resources that would be counted in this plan are small hydroelectricity, wind, solar, and biomass. The government expects that up to 2,000 megawatts of new wind capacity could be added to the current 1,340 megawatts before 2007, with biomass contributing 1,000 megawatts, small hydropower 800 megawatts, solar thermal 140 megawatts, waste-to-energy 100 megawatts, and grid-connected solar photovoltaic 15 megawatts. In recent years, bagasse (crushed sugar cane) cogeneration potential in cooperative and public-sector sugar mills has looked promising. Currently India has about 213 megawatts of installed bagasse cogeneration capacity, and another 263 megawatts is under construction at 29 plants.

Malaysia

Malaysia is another developing Asian country pursuing the development of large-scale hydropower. The country's Bakun hydroelectric project has been plagued by controversy and financial difficulties since it was first approved in 1994 [***48***]. The 2,400-megawatt project was scaled back in 1998, because the Asian economic crisis made the project too expensive to pursue, particularly given the sharp drop in electricity demand associated with the recession; however, the government recently announced that it would return to the original capacity of 2,400 megawatts. Bakun is expected to cost around $2.4 billion, and it is scheduled for completion in 2005. Environmentalists argue against the dam, which will require that more than 172,000 acres of farm land—an area larger than Singapore—be flooded to serve as a reservoir for the 670-foot dam. The reservoir will submerge 15 villages of the indigenous Iban people in central Sarawak state, as well as destroying the habitat of some 100 endangered species [***49***].

On the other hand, the Malaysian government argues that electricity from the Bakun dam will be necessary to support expanded industrial activity in the region, as well as to diversify the Malaysian electricity fuel mix, which is dominated by natural gas. The government announced that three resource-based industries (oil

Biomass Resource Utilization in Bangladesh (Continued)

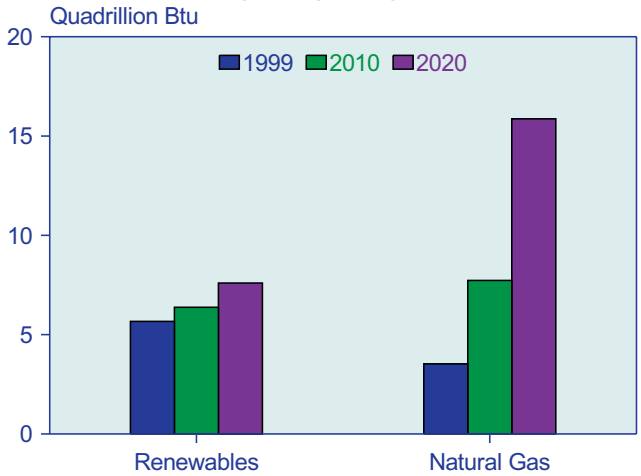
Bangladesh's Local Government Engineering Department provided the initial funding and paid for the entire system. The school pays for the operating and maintenance costs, which have been negligible. Although there have been successful installations of other biodigesters in the community, the school has not expanded its own biodigester program. The principal barriers to further commercialization of the technology are high capital costs and lack of financing options.

Despite the potential for problems associated with high capital costs, competing uses of biomass, availability of adequate quantity and quality of feedstocks, and lack of financing mechanisms, it is expected that biomass will continue to play a key role in supplying the energy needs of Bangladesh. The major question is how quickly more efficient biomass-using technologies can be introduced to allow the people of Bangladesh to obtain maximum benefit from the resource.

palm, cocoa, and wood) and four non-resource-based industries (electronics and engineering, manufacturing, petrochemicals, and steel) in Sabah and Sarawak will be the primary consumers of the electricity generated by Bakun [***50***]. The Sabah government has said it will open three industrial parks—Kudat Industrial Estate, the Integrated Timber Complex, and Palm Oil Industrial Cluster—that will consume an estimated 600 megawatts of electricity to be supplied by Bakun. Sarawak is expected to take about 500 megawatts of Bakun's electricity and neighboring country Brunei up to 500 megawatts; Kalimantan province in Indonesia is expected to take 100 megawatts. Upon completion, Bakun's capacity will be 1,700 megawatts, 700 megawatts below the full design capacity of 2,400 megawatts, because water levels are not expected to be sufficient initially to operate the generator at maximum capacity.

In addition to the large-scale hydroelectric expansion of Bakun, the Malaysian government has indicated an interest in developing the country's less controversial renewable resources. In 2001, the Malaysian government announced that it would like renewable energy to account for 5 percent of total power generation by 2005 [***51***]. The government hopes to support the development of renewables with its new Small Renewable Energy Power (SREP) program. Under the program, small power producers using renewable energy will be given a license for a 21-year period (from the date by which a plant is commissioned) to sell their power through the national power grid. The renewable energy sources permissible under the SREP program include biomass, biogas, municipal waste, solar, mini-hydro, and wind.

Figure 71. Renewable Energy and Natural Gas Consumption in Central and South America, 1999, 2010, and 2020



Sources: **1999:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **2010 and 2020:** EIA, World Energy Projection System (2002).

While the plant size can be greater than 10 megawatts, the maximum capacity for power exports to the national distribution grid cannot exceed 10 megawatts.

Vietnam

Vietnam also proposes expanding its large-scale hydroelectric power over the next several years. In 2001, Vietnam's National Assembly approved construction of the 3,600-megawatt Son La hydropower project to be constructed on the Da River, about 200 miles west of Hanoi [***52***]. The project is the subject of some dispute, even among members of the National Assembly, because it has been sited for an area known to have frequent seismic disturbances, and it opposed by human rights activists because it would require the relocation of up to 700,000 people, mostly of ethnic minorities. Estimates for the cost of constructing Son La (which is scheduled for completion in 2016) have run as high as $5.1 billion. Proponents of the project have argued that it is needed to help improve Vietnam's electricity fuel mix, reduce flood damage, and improve irrigation in the Red River Delta.

Pakistan

In Pakistan, several smaller hydroelectric and non-hydroelectric renewable projects were initiated in 2001. Work began on the Malakand III hydroelectric power project in September. Malakand is located at Dargai, Northwest Frontier Province, about 50 miles north of the Peshawar, which is considered the gateway to the Khyber Pass [***53***]. The project, which is being built by the Canadian Southern Electric Power Company, is scheduled for completion in 2005. In addition to the electricity to be generated by the dam, it should provide irrigation for some 20,000 acres of barren land.

Central and South America

Hydroelectricity is an important source of electricity generation in Central and South America. (In Brazil, the region's largest economy, hydropower typically supplies more than 90 percent of the country's electricity generation.) As a result, drought can have a devastating impact on electricity supply, and many countries of Central and South America are initiating projects to diversify the mix of electricity supply. Much of the diversification will consist of adding natural-gas-fired electricity capacity to reduce dependence on hydropower. As a result, although there is some projected growth in the use of hydroelectric and other renewable resources in the forecast, it is expected to be much less than the growth in natural gas consumption. In the *IEO2002* reference case forecast, demand for hydroelectricity and other renewables in Central and South America increases by only 0.8 percent per year between 1999 and 2020, whereas natural gas use in the region grows by 8.2 percent per year (Figure 71).

Rural electrification has also become an important issue for many Latin American countries. An estimated 75 million people in Latin America live without electricity [**54**]. In remote, rural locations where national electricity grids do not reach, renewable resources other than hydroelectricity are increasingly being used by government to bring electricity and telecommunications to the residents. Brazil, Chile, and Argentina, for instance, all have federal programs in place to improve access to electricity through off-grid renewable resources.

Brazil

In 2001, Brazil faced its worse drought in decades, which had a major impact on electricity supply (see also box on page 118). The country's reservoirs were, on average, 28 percent below normal capacity and in June the government was forced to initiate energy conservation and rationing measures in an effort to reduce electricity consumption by 20 percent [**55**]. The effort was largely successful in the first 2 months, with many regions meeting or exceeding their 20-percent demand reduction goal, but in August consumption was reduced by only 15 to 18 percent [**56**]. In an effort to improve the conservation effort, the government expanded an existing bonus scheme to benefit 75 percent of families living in energy rationing areas, as opposed to the previous 60 percent. Those who achieve a 20-percent savings and consume less than 225 kilowatthours per month will receive 1 real credit (about $0.37) for every 1 real of energy saved. Previously, only those consuming up to 100 kilowatts were eligible for a bonus.

Although the country missed its targets in August, the Brazilian government announced that there was no risk of blackouts for the remainder of the year because water levels were about 3 percent higher than had been projected. In addition, according to the government, even in a worst case scenario—where rainfall was only 61 to 63 percent of normal levels—rationing would be extended into 2002, but at the lower rate of 5 percent of consumption.

In addition to the rationing and conservation strategies, Brazil is rushing to add additional capacity. By the end of 2002, Brazil plans to add 9,034 megawatts of natural-gas-fired electricity generation capacity, 6,381 megawatts of hydroelectric capacity, and 400 megawatts of mini-hydro capacity [**57**]. One of the hydroelectric projects included in the plans is the 112-megawatt Porto Estrela project on the Santo Antonio River, which began operating in October 2001 [**58**]. The project was constructed by a consortium led by Brazil's Cemig power company at a cost of $50 million. It was built in record speed, with only a 26-month construction period.

In June 2001, Brazil's electricity regulator, Aneel, sold eight licenses to build and operate hydroelectric facilities in six southern Brazilian states. The licenses netted the government about $1.1 billion [**59**]. The six plants will add a total of 2,282 megawatts of power to the national energy grid. The largest project, which will be constructed by a consortium led by mining company Companhia Vale do Rio Doce (CVRD), is an 840-megawatt plant in the southern state of Rio Grande do Sul. Other plants will be located in the states of Santa Catarina, Parana, Rio Grande do Sul, Minas Gerais, Goias, and Tocantins. Brazil's southern region is not suffering from the drought that has hit other parts of the country, and the plants are expected to be completed between 2006 and 2008. Licenses were awarded in November for 11 additional hydroelectric power plants in Brazil, which are expected to add 2,700 megawatts of generating capacity by 2007 [**60**].

The government of Brazil is also working to develop nonhydroelectric renewables, especially in remote areas of the country that do not have access to the electricity grid. In 1998, the country started the National Program for Energy Development of States (PRODEEM) in an effort to install 20,000 megawatts of renewable energy capacity, with an investment of about $25 billion in photovoltaic and other renewable energy technologies [**61**]. The project's aim was to expand electricity capacity through hundreds of community projects—each expected to reach about 200 people living in rural communities that would not be connected to an expanding electricity grid before 2003. In addition to photovoltaics, the PRODEEM program included aero-generators and wind turbines, small central hydroelectric plants, biomass-derived fuels (alcohol, vegetable oils, forest and farm wastes), and biodigesters.

Brazil is now launching a successor program to PRODEEM called ALVARADO, which will focus on increasing access to electricity in the northeastern part of the country. Starting in 2002, ALVARADO is expected to begin establishing small renewable energy systems. Like PRODEEM, ALVARADO will involve both local and international private-sector developers in its effort to install off-grid renewable energy projects.

Another Brazilian scheme to promote the development of renewable energy resources involves electricity produced from sugar cane. The second-largest distributor of electricity in São Paulo state, CPFL, has set a target to increase its marginal power purchases from sugar cane industries to 7 percent of its total demand by 2003. Further, the Pernambuco state power company (owned by Spain's Iberdrola) has agreed to purchase all the electricity that is produced by the Cruangi sugar refinery through 2006.

Chile

In Chile, the controversial and much-delayed 570-megawatt Ralco hydroelectric project was delayed for another 6 months. The $540 million project being developed by

Energy Crisis in Brazil: Implications for Hydropower

Brazil is currently in the midst of an energy crisis that has exposed the risk that accompanies its high level of dependence on hydroelectric power. After the worst drought in 70 years, water levels in many of Brazil's hydroelectric reservoirs fell to critical lows by the summer of 2001. To avert impending blackouts and power interruptions, the Brazilian government introduced a series of emergency measures intended to cut electricity consumption and diversify supply sources.

As of June 1, 2001, industries and commercial businesses were required to reduce their power consumption by 15 to 25 percent.[a,b] They were also barred from undertaking any major new expansion works requiring new electricity connections from the main system.[c] Households that consume more than 100 kilowatthours of electricity per month were required to cut their consumption by 20 percent or face a 3- to 6-day cut in their electricity supply.[d] The electricity rationing plans were initially implemented in areas of the South East, North East, and Center West regions of the country, then extended to three more states (Pará and Tocantins in the North, and Maranhão in the North East) as of July 1 (see map below).

Electricity consumption dropped during the first few months of the rationing program, but reduction levels did not reach the 20-percent target in most regions.[e] The program was initially expected to conclude in November, but the government announced in October that it would extend the rationing and initiate further demand-side measures. The government ordered a 4-day work week in several states and created three new "holidays" (October 22 and November 16 and 26) in North Eastern states, intended to help spur electricity consumption reductions in the manufacturing and buildings sectors.[f] The new measures also required that power be cut off to residential customers using more than 500 kilowatthours of energy per month. Daylight savings measures were also introduced in most regions of the country.

(continued on page 119)

[a]"Brazil: Power Rationing Begins," *World Markets Online*, web site www.worldmarketsonline.com (June 4, 2001).

[b]"Brazil: Government Loosens Electricity Penalties," *World Markets Online*, web site www.worldmarketsonline.com (June 6, 2001).

[c]With the exception of residential and rural projects.

[d]Initially, the noncompliance penalty for residential customers included surcharges. Under mounting public pressure, the government eliminated the surcharge penalties and relaxed the conditions for supply cuts. Power will now be cut off only for households that fail to meet their target for two consecutive months (3 days for the first offense, 6 days for the second offense).

[e]"Electricity Rationing Extended to April," *Latin America Monitor*, Vol. 18, No. 8 (August 2001).

[f]"Extra Holidays To Help North East Meet Power Saving Target," *World Markets Online*, web site www.worldmarketsonline.com (October 11, 2001).

Energy Crisis in Brazil: Implications for Hydropower (Continued)

In December 2001, regional energy rationing targets (with the exception of heavy industry in each region) were lowered.[g] In January 2002 the Brazilian government eased the power rationing targets for heavy industry to 10 percent of mid-2001 consumption,[h] and all energy rationing was discontinued on March 1, 2002. According to the Brazilian national grid operator, ONS, water reservoir levels had increased sufficiently to guarantee power supply through 2002 and 2003, given the long-term forecasts for rainfall.[i]

Although more than 90 percent of Brazil's generating capacity and production currently comes from hydroelectric plants, the drought was not the sole factor behind the country's energy crisis. The demand for electricity in Brazil has been growing by almost 5 percent per year, on average, since 1990. Demand growth has been driven particularly by industrial use in the South East and Center West regions, where most of the country's population live. However, investments in new electricity generation and transmission capacity have not kept pace with demand. The Brazilian government now plans to build 49 new thermoelectric generators by 2003, fueled primarily by Bolivian natural gas; only a handful have come online so far. The absence of power line connections to regions of the South and the North of Brazil, as well as from Argentina, has prevented electricity from reaching the areas facing electricity shortages.

Factors such as private investors' increased perception of risk since the devaluation of the Brazilian real in 1999, the contractual terms of supply offered for natural gas by Petrobras (the federal oil and gas monopoly), and the electricity tariff controls set by Aneel (Brazil's power regulator) are believed to have impeded the capital investments needed to finance new generation and transmission projects in the country.[j] The slowdown in efforts to privatize the electricity sector in recent years has also contributed to the current energy crisis, because some planned capacity additions were to occur after privatization.

Changes that have occurred since the onset of the rationing program have helped to remove some of the financial and regulatory barriers to electricity sector investment in Brazil.[k] Specifically, the National Development Bank of Brazil made several billion dollars worth of public funds available to companies wishing to enter partnerships in natural-gas-fired or hydroelectric power stations. The bank will provide up to 60 percent of the financing needed by private investors. A formula has also been established to protect investors against exchange rate risk. Furthermore, Petrobras has agreed to a set of supply terms that are considered more favorable by thermoelectric power plant investors, with natural gas to be provided at fixed prices for periods of 12 full months. On the transmission side, the Inter-American Development Bank has approved $243.9 million in financing to build an additional 1,000-megawatt line connecting the electricity grids of Argentina and Brazil.

Substantial governmental effort on the supply side has focused on natural-gas-fired generating plants, which can be brought online faster and at less expense than most other comparable options. Despite the difficulties associated with depleted reservoirs, a significant expansion of Brazil's hydropower infrastructure is also considered a key element of the government's overall plan to shore up the country's electricity supply. Aneel awarded licenses for the construction and operation of 8 new hydroelectric power plants in June 2001, and licenses for another 11 were awarded in November.[l] These new builds alone would add some 5,000 megawatts to Brazil's total generating capacity. The government has also expressed its intention to increase capacity from the country's third largest power generator, CESP Parana, in advance of its privatization. The reservoir quota for Itaipu—the world's largest hydroelectric plant—may also be increased in order to boost generation.[m] Both CESP Parana and Itaipu serve the energy-starved South East region of Brazil.

Although expansion of the hydroelectric infrastructure may serve to alleviate electricity shortages in Brazil, it is not without controversy. The development of Brazil's existing hydroelectric facilities has given rise to

(continued on page 120)

[g]"Power Rationing Reduced," *World Markets Online*, web site www.worldmarketsonline.com (November 23, 2001).

[h]Power-Saving Targets for Industry Reduced," *World Markets Online*, web site www.worldmarketsonline.com (January 25, 2002).

[i]"Power Rationing To End on 1 March," *World Markets Online*, web site www.worldmarketsonline.com (February 20, 2002).

[j]A. de Oliveira, "The Changing Brazilian Electricity Market," Roundtable / Conference Reports, Institute of the Americas (March 27, 2000); "Brazil Stares Electricity Rationing in the Face," *Financial Times: Power in Latin America*, No. 70 (April 2001); "Biting the Hand That Electrifies," *Financial Times: Power in Latin America*, No. 71 (May 2001).

[k]"Investing in Brazil Is Anything But Boring," *Financial Times: Power in Latin America*, No. 74 (August 2001).

[l]"Government Sells Licenses for New Hydroelectric Power Plants," *World Markets Online*, web site www.worldmarketsonline.com (June 29, 2001); "Brazil: Aneel Sells Licenses to Build 11 New Hydroelectric Plants," *World Markets Online*, web site www.worldmarketsonline.com (December 3, 2001).

[m]"Brazil Stares Electricity Rationing in the Face," *Financial Times: Power in Latin America*, No. 70 (April 2001).

Endesa España has been the subject of much criticism from environmentalists and human rights activists for its treatment of the indigenous Pehuenche people. Construction of Ralco will include flooding of some sacred Pehuenche land and will dislocate 91 families that currently live there [***62***]. In 2001, the problems were compounded by heavy rains in the late spring that caused the Bio Bio River to rise to five times its normal level. The dike constructed to reroute the river above the construction site collapsed, and the river reestablished its original course. As a result, construction was halted and did not resume until December, when river levels were low enough to allow reconstruction of the diversion dike. The project has been under construction for some 7 years, and the original completion date has been delayed for at least a year; it is now expected to be completed by January 2004 at the earliest.

Chile's National Energy Commission is planning to implement several projects that will involve nonhydroelectric renewable energy resources [***63***]. The government has passed legislation promoting the development of 120 new geothermal projects by independent power producers. The National Electricity Commission has initiated an aggressive rural electrification program aimed at providing electricity to communities that lack access to the national electricity grid. Since 1992, Chile has invested $112 million in the program, which is expected to run until 2004, with the goal of supplying electricity to 100 percent of the population.

Other Central and South America

Other Central and South American countries are also attempting to address the problem of getting electricity to remote, rural areas. Costa Rica has one of the most ambitious programs for renewable energy in Latin America. The country instituted a policy mandating that by 2025 all forms of energy consumed in the country be derived from renewable sources. In Honduras the Inter-American Development Bank has estimated that almost 40 percent of the population does not have access to electricity. The Bank has approved a $5 million loan for a study to determine whether combining education and health assistance with telecommunications and energy technology for low-density populations is feasible [***64***]. The study will begin with two villages, providing solar thermal and photovoltaic home systems. If it is deemed a success, the Bank has indicated that it would allow as many as 100 villages to take part in the project.

In Argentina, the government and the World Bank are implementing a project that is to provide electricity to roughly 70,000 rural households and 1,100 provincial public service institutions, principally through the use of renewable energy systems [***65***]. Total cost of the project has been estimated at $120.5 million. Energy sources will be principally photovoltaic and wind, with biomass used to make up any shortfalls. Argentina has expressed a particular interest in developing its wind resources. The country has passed legislation that requires all utilities to purchase wind power if it is available. This should help cover the costs of building the necessary transmission infrastructure from the wind turbines to the power distributors. Further, with approval of the Argentine government, Spanish companies Endesa and Elecnor are developing 3,000 megawatts of wind energy capacity, to be completed by 2010.

In a region like Latin America, where the grid is often underdeveloped and a large number of people live in rural areas without access to electricity, photovoltaics are promising because they can be installed and operated at the point of energy consumption. Roughly 75 million people in Latin America live without electricity because of inadequate transmission infrastructure. It can cost between $1,000 and $2,000 per mile to extend low-voltage distribution lines to the transmission grid. As a result, in areas where the population is so dispersed that load density can be as small as one customer per mile of line, the cost of extending remote sites to the transmission grid can be prohibitive. On the other hand, off-grid, individual photovoltaic systems average $647

Energy Crisis in Brazil: Implications for Hydropower (Continued)

some economic, social, and environmental problems. The construction of large hydroelectric projects in particular, often beset by long delays and significant cost overruns, has contributed to the country's debt burden since the 1970s. Reservoir and dam development for large facilities has also disrupted the culture and sources of livelihood for many communities. Studies have indicated that the majority of people uprooted from their existing settlements as a result of dam development are poor and / or members of indigenous populations or vulnerable ethnic minorities.[n] The displaced populations have also had to bear a disproportionate share of the social and environmental costs of large hydroelectric projects without gaining a commensurate share of the economic benefits. Reservoir and dam development for hydroelectric facilities has also led to loss of forests, wildlife habitats, species populations, aquatic biodiversity, upstream and downstream fisheries, and services provided by downstream flood plains and wetlands.

[n]World Commission on Dams, *Dams and Development: A New Framework for Decision-Making* (London, UK: Earthscan Publications, 2000).

per installed household unit, assuming a system of 50 watts per household. As a result, the more remote the site, the more financially attractive photovoltaic systems can be.

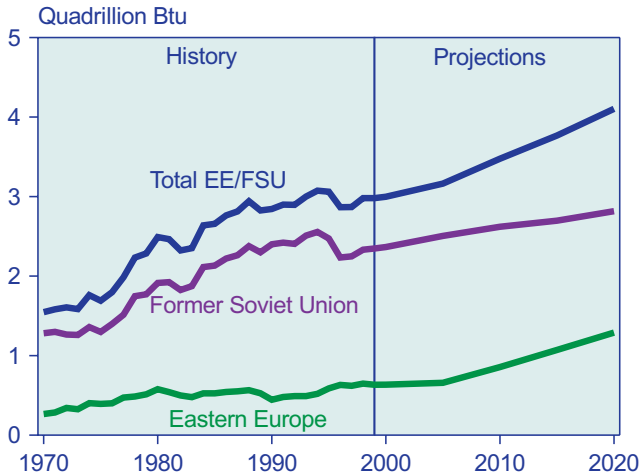
Eastern Europe/Former Soviet Union

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 1999 to 2020 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. FSU renewable energy demand is projected to increase by 1.6 percent per year. In Eastern Europe, the growth rates projected for hydroelectricity and other renewables are twice those for the FSU at 3.5 percent per year, reflecting the relatively small amount of renewable capacity currently installed in the region. By 2020, the reference case projects that use of hydropower and other renewables in Eastern Europe will be 55 percent of the current level in the FSU (Figure 72).

Former Soviet Union

Azerbaijan is one of the few former Soviet republics that has added new, large-scale hydroelectric power capacity. In May 2000, the 4,000-megawatt Yenikand hydroelectric facility was completed [***66***]. The project, originally begun in 1985, was later suspended and could only be started again in 1996 with the help of a $53 million loan from the World Bank. The country's 360-megawatt Mingechaur hydroelectric power station is currently undergoing rehabilitation and should begin operation in the near future.

Figure 72. Renewable Energy Consumption in Eastern Europe and the Former Soviet Union, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

Georgia also plans to add hydroelectric capacity and repair some of the country's existing hydropower facilities. There are plans to construct two hydroelectric plants on the Rioni River, the 250-megawatt Namakhvani and the 100-megawatt Zhoneti [***67***], and a 40-megawatt Minadze hydroelectric plant on the Kura River. In November 2002, Georgia announced a tender for work to be done on the country's largest hydropower project, the Inguri. The estimated $62 million project is designed to increase the facility's capacity to 1,300 megawatts from the current level of around 400 megawatts. The project will be funded in part by a long-term credit from the European Bank for Reconstruction and Development, along with funds from the European Union and Japan and the Georgian government.

In 2001 there were some modest attempts to increase the use of nonhydroelectric renewables in a few countries of the FSU. In July, Ukraine's parliament passed the Ukrainian Wind Power Development Project in an attempt to encourage the development of wind power and make wind power a "significant source" of electric power by 2020 [***68***]. Ukraine has extensive wind resources, although the development of a wind power industry would require technological and financial support.

A Malaysian company, Ideal Fortune Holdings Sdn. Bhd., has been awarded a 25-year concession to build, own, operate, and transfer wind and hydroelectric power projects in Kazakhstan [***69***]. A combined capacity of 500 megawatts is to be added in Kazakhstan. The wind facilities are to be located in the Chilik Corridor, a valley 90 miles north of the city of Almaty. They will cost an estimated $500 million and should be completed by 2006.

Eastern Europe

Much of Eastern Europe has been experiencing drought conditions over the past year, which has constrained electricity generation from the region's hydroelectric facilities. To counteract the decline in reservoir levels, there are some plans to expand the capacity of existing hydroelectric facilities throughout the region, as well as some plans to construct new facilities.

Albania has been particularly hard hit by the drought, and other countries have attempted to alleviate the resulting electricity shortages with exports or by increasing water flow at Albania's hydropower projects. In 2000, Macedonia allowed waters from Lake Ohrid to drain into the Black Drin River to increase the flow at Albanian hydroelectric projects downriver [***70***]. Croatia announced plans to construct a new hydroelectric

project on the Drava River that would be able to provide power to Albania. Likewise, Italy's Enelpower announced plans to construct a 100-megawatt hydroelectric project on the Vjosa River in Albania that would be able to supply power to Albania, Greece, or Italy (by submarine cable) as needed. China has agreed to build a hydropower plant on the Drini River that is expected to produce 350 million kilowatthours of electricity each year.

At the end of July 2001, Albania's state-owned electric utility, Korporata Elektroenergjetika Shqiptare (KESH) imposed daily power cuts of up to 10 percent on electricity consumption to conserve water reserves until the rainy season arrived. The International Monetary Fund urged the government to act quickly to avoid the blackouts that occurred in the previous year when summer droughts led to 12-hour-a-day blackouts during the winter.

KESH also signed an agreement with Croatia's largest electrical equipment manufacturer, Koncar Inzinjering, to repair and upgrade two hydroelectric facilities on the Mat River in central Albania [***71***]. The agreement will include the upgrade of generators, transformers, and switchgear at the 25-megawatt Ulza and 25-megawatt Shkopeti power plants. The $2.9 million project is being financed by the European Bank for Reconstruction and Development and should be completed by the end of 2003. Koncar will also work with Bosnian Croat power utility Elektropivreda HZ Herceg Bosne (EP HZ HB) to complete Bosnia's Pec-Mlin and Mostarsko Blato hydropower plants, at an estimated cost of around $87.9 million [***72***].

Romania's Hidroelectrica is in the process of completing, upgrading, and restoring 14 of its hydroelectric facilities [***73***]. The plants, in various stages of construction, would add a combined 780 megawatts of installed capacity. One project, the Siriu-Surduc-Nehoiasu hydroelectric project on the Buzau River in eastern Romania, is being handled by United Power Company, a joint venture between Hidroelectrica and U.S. Harza. The project was to be completed in the first quarter of 2002. The expansion of the Iron Gates I (located on the Danube River) refurbishment project began in 1999. The $154 million contract includes restoration of six turbines and should boost capacity of the facility to 1,290 megawatts from the present 1,070 megawatts. The project is scheduled for completion by 2005.

There are a few plans to develop nonhydroelectric renewable energy resources in Eastern Europe. In 2001, a German renewable energy company, P&T Technology, announced plans to construct a series of wind power plants in Poland [***74***]. P&T has already reached agreements to construct 150 megawatts of wind power capacity and has obtained the approval of the local Polish communities. The projects are located in the northwestern coastal area of the country. The first, a 4-megawatt wind farm, is being constructed near Kolobrzeg, Poland.

Hungary has also begun looking toward developing wind power. A 600-kilowatt wind turbine in the Hungarian village of Kulcs (about 40 miles south of Budapest) began operating at the end of August 2001 and will supply electricity to the public electricity grid [***75***]. The project is expected to provide around 1.2 million kilowatthours of electricity annually, enough to supply 750 households. The $700,000 project is owned by Emszet (First Hungary Windpower), majority owned by Eon Hungaria, and was subsidized by government grants that covered 40 percent of the installation costs. The Hungarian government has established a target of having renewables supply 6 percent of the country's total energy production by 2010, from an estimated 2 to 3 percent currently. The Emszet wind generator is the second working unit in Hungary. The first was a 250-kilowatt unit built by Bakony Power in Inota, western Hungary. The Inota project cost $428,000 and began operating in December 2000. Electricity from the project is fed into the local power station before being sold onto the national grid.

Africa/Middle East

In Africa and the Middle East, hydroelectricity and other renewable energy sources have not been widely established, except in a few countries. In the Middle East, only Turkey and Iran have extensively developed their hydroelectric resources. In Africa, Egypt and Congo (Kinshasa) have the largest volumes of hydroelectric capacity. Other countries, including Ivory Coast, Kenya, and Zimbabwe, are almost entirely dependent on hydropower for their electricity, not because they have extensively developed hydropower resources but rather because of a lack of development of electricity infrastructure. Renewable energy use in Africa and the Middle East is projected to rise from 1.2 quadrillion Btu in 1999 to 2.6 quadrillion Btu in 2020 in the *IEO2002* reference case (Figure 73).

In Africa, a number of hydroelectric projects moved forward in 2001. The Japanese government approved implementation of the delayed Sondu Miriu hydroelectric project in Kenya [***76***]. Funding for the 60-megawatt project in Nyakach had been partially withheld because of environmental concerns from local residents and nongovernment organizations. The Japanese Ministry of Foreign Affairs and representatives from the Japanese Bank for International Cooperation reviewed the project and met with those opposing it to reach consensus as to whether the project should continue. An agreement was reached in June 2001, and the $52 million Sondu Miriu is expected to be completed by the end of 2003.

Uganda is also expected to see some hydroelectric projects begin operation over the next several years. A consortium of companies led by U.S. AES is constructing the 200-megawatt Bujagali hydroelectric project, to be located about 2.5 miles south of the source of the White Nile River at Lake Victoria [***77***]. The project is expected to cost an estimated $500 million to build and is scheduled for completion before the end of 2005. Bujagali will increase Uganda's electricity capacity by more than 40 percent, and a portion will be exported to neighboring Kenya and Tanzania.

There is also a move to increase the use of small-scale hydroelectric power in Uganda. In 2001, the country issued tenders for the development of a 5-megawatt hydropower station at Nyagak Falls in the Nebbi District and a 1.5-megawatt plant at Olewas Falls (the latter to be financed by the World Bank). The two projects will cost an estimated $18 million. No construction schedule has been released.

The River Senegal Basin Development Organization (OMVS) announced that all three member nations, Senegal, Mali, and Mauritania, should begin receiving electricity from the long-awaited Manantali hydroelectric project in Senegal by April 2002 [***78***]. The dam portion of the project was actually completed in 1987, but funding problems and military tensions between Mauritania and Senegal stopped the completion of the power station and transmission lines [***79***]. The 200-megawatt project cost a total of $267 million to construct.

Other African hydropower projects that moved forward in 2001 include the Zambian 120-megawatt Itezhi-Tezhi, to be located in the southern part of the country [***80***]. Tenders were issued in July 2001 for construction of this $105 million project, which should be completed by July 2003.

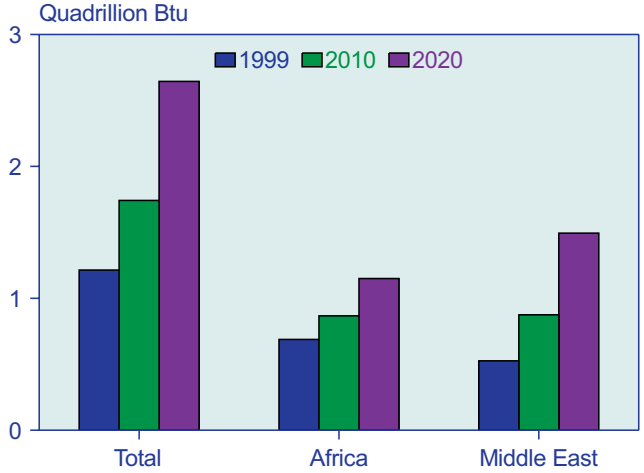
Mozambique's proposed Mepanda Uncua project—to be located downstream from the existing Cahora Bassa dam on the Zambezi River—also moved forward in 2001 [***81***]. The 1,200-megawatt Mepanda Uncua project will cost an estimated $1.25 billion. In April 2001, the Mozambican government released results from its environmental impact study. The study indicated that potential environmental damage from the new project would be minimal, and that the project should proceed.

Finally, the Saudi Fund for Economic Development, the Abu Dhabi Fund for Development, the Arab Fund for Economic and Social Development, and the Kuwaiti Fund for Economic Development have jointly decided to fund the construction of a 1,250 megawatt hydroelectric project in Sudan [***82***]. The Merowe dam project is to be constructed at a cost of about $780 million and will be located about 220 miles north of Khartoum on the Nile River. Tenders are scheduled to be issued for construction of the project in 2002.

There were also several advances in the development of nonhydroelectric renewable energy projects in Africa. Morocco continued its pursuit of installing wind power. The state-owned utility Office Nationale d'Electricite (ONE) is planning to construct 200 megawatts of wind power at Tangiers and Tarfaya. The country's first wind power plant, the 50-megawatt Koudia al-Baida, began operating in May 2000 and is generating an estimated 200 million kilowatthours of electricity annually. Egypt also has made some advances in wind power, installing 30 megawatts of wind capacity on the Red Sea coastline south of Cairo in 2000, with plans to add another 60-megawatt build-own-operate-transfer (BOOT) wind project at Zafrana [***83***]. The Egyptian New and Renewable Energy Authority (affiliated with the state-owned Egyptian Electricity Holding Company) hopes that wind will supply some 600 megawatts of electricity capacity to the national grid by 2007.

In the Middle East, much of the new development in renewable energy, particularly hydroelectricity, is centered in Turkey. The country has ambitious plans to construct a system of 21 dams and 19 hydroelectric plants, called the Southeast Anatolia Project (GAP) [***84***]. It is a joint hydroelectric power and irrigation project. Upon completion, the $32 billion project will have a combined installed capacity of 7,500 megawatts. As of 2000, six of the hydropower plants had been completed (Karakaya, Ataturk, Kralkizi, Dickle, Batman, and Karkamis); three were under construction (Birecik, Kayacik, and Sanliurfa); and six others were in the planning phase (Erkenek, Garzan, Silvan, Adiyaman, Ilisu, and Cizre).

Figure 73. Renewable Energy Consumption in Africa and the Middle East, 1999, 2010, and 2020



Sources: **1999:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **2010 and 2020:** EIA, World Energy Projection System (2002).

In recent years, Ilisu has been the most controversial project in the GAP scheme. The proposed 1,200-megawatt project would be the largest hydropower project on the Tigris River in the southern part of Turkey. The UK government was asked to provide export credit guarantees for construction of the $1.8 billion project by Balfour Beatty, a British civil engineering company, which has a contract worth nearly $290 million for construction work on Ilisu [***85***]. Environmentalists oppose the dam on the grounds that it will mean that more than 90 villages will be submerged by the reservoir that is to support the dam, and that it will force the relocation of up to 78,000 people, mostly of the minority ethnic Kurds [***86***]. The British government initially granted Balfour Beatty's guarantees, but amidst substantial protests it indicated that it might withdraw its support for the dam because of environmental concerns, leading Balfour Beatty to pull out of the project in November 2001 [***87***].

In a similar development, the UK government is considering whether to guarantee Turkey's $844 million Yusefeli hydropower project [***88***]. The British construction firm Amec, which is part of a consortium seeking to build the Yusefeli hydroelectric dam, has applied to the British Export Credit Guarantee Department for a loan of $96 million. Detractors of the project argue that up to 15,000 people—largely minority Georgians—would have to be relocated to construct Yusefeli.

Other hydroelectric projects are progressing in Turkey. In October 2001, a consortium of companies led by the Washington Group International announced that it had been awarded a planning contract to provide geotechnical exploration, engineering, and design for the first phase of the Hakkari dam, to be constructed on the Zap River in Southern Anatolia [***89***]. The $600 million project will consist of a 558-foot dam, a 7-mile tunnel, and a 208-megawatt hydroelectric power station. Construction of the first phase is scheduled for completion by mid-2002.

References

1. "Surprise, Surprise! Ting Gets Bakun Contract," *Financial Times: Power in Asia*, Vol. 331 (June 28, 2001), p. 12.
2. P. Gall, "Brazil's Natural Gas Market Simultaneously Beckons, Threatens," *The Oil Daily*, Vol. 51, No. 169 (August 31, 2001), p. 4.
3. American Wind Energy Association, "Global Wind Energy Market Report: Wind Energy Growth Was Steady in 2000; Outlook for 2001 Is Bright," press release (May 2001), web site www.awea.org/faq/global200.html.
4. International Energy Agency and National Renewable Energy Laboratory, *IEA Wind Energy Annual Report 2000* (Golden, CO, May 2001), p. 46.
5. "Europe Launches Its (Half-Hearted) Push for Renewable Energy," *World Gas Intelligence*, electronic edition (September 19, 2001).
6. Energy Information Administration, *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001), p. 95.
7. Energy Information Administration, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, November 2001), pp. 71 and 72.
8. Energy Information Administration, *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001), p. 98.
9. "Canadian News: Northern Province Proposes More Than 12,000 MW on Six Rivers," *Hydro•Wire*, Vol. 22, No. 15 (August 6, 2001), p. 2.
10. "Crees Consent to Quebec's 1,200-MW Eastmain-Rupert," *Hydro•Wire*, Vol. 22, No. 21 (October 29, 2001), p. 405.
11. "Alcoa Joins Newfoundland Study of 2,800-MW Lower Churchill," *Hydro•Wire*, Vol. 22, No. 15 (August 6, 2001), pp. 2-3.
12. "Quebec Approves 526-MW Toulnustouc," *Hydro•Wire*, Vol. 22, No. 18 (September 16, 2001), p. 4.
13. "Quebec Begins Studies of 450-MW Peribonka Project," *Hydro•Wire*, Vol. 22, No. 20 (October 15, 2001), p. 1.
14. "Canadian Renewable Energy Evaluates Hydro Development Sites," *Hydro•Wire*, Vol. 22, No. 18 (September 16, 2001), p. 4.
15. Acres International Limited, "Misema: Small Hydro Development," press release (August 2001).
16. "News Briefs: St. John's, Newfoundland," *Hydro•Wire*, Vol. 22, No. 18 (September 16, 2001), p. 7.
17. American Wind Energy Association, "Global Wind Energy Market Report: Wind Energy Growth Was Steady in 2000; Outlook for 2001 Is Bright," press release (May 2001), web site www.awea.org/faq/global200.html.
18. "Canada Implements Production Tax Credit," *Wind Energy Weekly*, electronic edition, Vol. 20, No. 975 (December 21, 2001).
19. "First Phase of SunBridge Wind Project Starts Sending Electricity to SaskPower," *Solar & Renewable Energy Outlook*, Vol. 27, No. 17 (September 1, 2001), p. 197.
20. Natural Resources Canada, "Saskatchewan's First Large-Scale Wind Power Project Planned for Gull Lake," press release (April 18, 2001), web site www.nrcan.gc.ca.

21. Natural Resources Canada, "Backgrounder: Wind Power Project in Prince Edward Island," press release (June 1, 2001), web site www.nrcan.gc.ca.
22. "Ontario Power Generation Starts Up Largest Turbine in N. America," *Wind Energy Weekly*, electronic edition, Vol. 20, No. 960 (August 17, 2001).
23. "Renewable Energy Enters Latin America Supply Mix," *Financial Times: Power in Latin America*, No. 75 (September 2001), pp. 9-12.
24. National Renewable Energy Laboratory, *IEA Wind Energy Annual Report 2000* (Golden, CO, May 2001), p. 129.
25. "Europe Launches Its (Half-Hearted) Push for Renewable Energy," *World Gas Intelligence*, electronic edition (September 19, 2001).
26. National Renewable Energy Laboratory, *IEA Wind Energy Annual Report 2000* (Golden, CO, May 2001), pp. 95-96.
27. "Europe Launches Its (Half-Hearted) Push for Renewable Energy," *World Gas Intelligence*, electronic edition (September 19, 2001).
28. "Germany Starts Up Europe's Largest Onshore Wind Farm," *Wind Energy Weekly*, electronic edition, Vol. 20, No. 960 (August 17, 2001).
29. National Renewable Energy Laboratory, *IEA Wind Energy Annual Report 2000* (Golden, CO, May 2001), pp. 67-69, 29, and 46.
30. "Today in Brief: TotalFinaElf Plans Wind Farm in Belgium," *World Markets Online* (July 11, 2001).
31. "ScottishPower Unveils Plans for UK's Largest Wind Farm," *Wind Energy Weekly*, electronic edition, Vol. 20, No. 957 (August 10, 2001).
32. BP p.l.c., "BP Announces a Five-Fold Expansion of Solar Production in Spain: Acquisition of Agere Systems' Plant in Madrid Offers Platform for Rapid Growth," press release (July 4, 2001), web site www.bp.com.
33. "BP To Invest in Solar in Spain," *The Oil Daily*, Vol. 51, No. 126 (July 6, 2001), p. 9.
34. "Overview of the Mandatory Renewable Energy Target," Office of the Renewable Energy Regulator, web site www.orer.gov.au (June 1, 2001).
35. National Renewable Energy Laboratory, *IEA Wind Energy Annual Report 2000* (Golden, CO, May 2001), p. 50.
36. "Victoria Wind Farm On Line," *Financial Times: Power in Asia*, Vol. 332 (July 8, 2001), p. 20.
37. "Q'ld Seeks Big Wind Power," *Financial Times: Power in Asia*, No. 336 (September 4, 2001), pp. 18-19.
38. National Renewable Energy Laboratory, *IEA Wind Energy Annual Report 2000* (Golden, CO, May 2001), p. 119.
39. "Plans for Hydropower Units," *Financial Times: Power in Asia*, No. 337 (September 18, 2001), pp. 19-20.
40. N. Guu, "Zhu Urges Speeding Up Resident Relocation," *China Daily* (July 19, 2001), p. 1.
41. M. Hurle, "Energy Sector Analysis: China: Construction of Longtan Hydro Plant Begins," *World Markets OnLine*, web site www.worldmarketsonline. com (July 2, 2001).
42. J. Monahan, "WB Move To 'clean Up' China," *Financial Times: Power in Asia*, No. 330 (June 14, 2001), pp. 2-3.
43. "ADB Power Lending Bounces Back," *Financial Times: Power in Asia*, Vol. 331 (June 28, 2001), pp. 4-5.
44. "Shell To Provide Solar Power," *Financial Times: Power in Asia*, Vol. 332 (July 8, 2001), p. 16.
45. "Narmada Oustees Still To Get a Home," *The Statesman* (New Delhi) (May 18, 2001).
46. "India: Water for Rajasthan by June 2004," *The Hindu* (Madras) (August 20, 2001).
47. "Delhi Stresses Renewables in Five-Year Plan," *Financial Times: Power in Asia*, Vol. 331 (June 28, 2001), pp. 9-10.
48. H. Thompson, "The Bakun Dam Is Back," *Earth Island Journal*, Vol. 16, No. 3 (Autumn 2001), p. 23.
49. R. Sullivan, "Giant Dam Plan Swamps Life in Longhouses," *The Herald* (Glasgow) (September 17, 2001), p. 12.
50. "Potential Bakun Power Customers 'Identified' at Last," *Financial Times: Power in Asia*, No. 336 (September 4, 2001), p. 11.
51. "KL Sets Renewable Target," *Financial Times: Power in Asia*, No. 330 (June 14, 2001), p. 9.
52. "Assembly Ok's Hydro Scheme," *Financial Times: Power in Asia*, Vol. 331 (June 28, 2001), pp. 18-19; and "Hanoi Looks at Dam Project," *Power in Asia*, Vol. 332 (July 8, 2001), pp. 14-15.
53. "New Boost For Hydro, Coal," *Financial Times: Power in Asia*, No. 337 (September 18, 2001), p. 10.
54. "Renewable Energy Enters Latin America Supply Mix," *Financial Times: Power in Latin America*, No. 75 (September 2001), pp. 9-12.
55. P. Gall, "Brazil's Natural Gas Market Simultaneously Beckons, Threatens," *The Oil Daily*, Vol. 51, No. 169 (August 31, 2001), p. 4.
56. "Brazil Widens Bonus Plan," *Financial Times: Power in Latin America*, No. 75 (September 2001), p. 17.
57. J. Prates, "Brazil's Energy Crisis Complicates Progress in Gas, Power Markets, But Outlook Brightening," *Oil & Gas Journal*, Vol. 99, No. 42 (October 15, 2001), pp. 77-84.

58. "Briefly Noted—Hydro," www.SolarAccess.com, weekly edition (posted October 24, 2001).

59. "Sale of Hydroelectric Concessions Brings R2.5 Billion," *Financial Times: Power in Latin America*, No. 73 (July 2001), p. 15.

60. J. Kerr, "Aneel Sells Licences To Build 11 New Hydroelectric Plants," *World Markets OnLine*, web site www.worldmarketsonline.com (December 3, 2001).

61. "Renewable Energy Enters Latin America Supply Mix," *Financial Times: Power in Latin America*, No. 75 (September 2001), pp. 9-12.

62. "Ralco Delayed Another Six Months," *Financial Times: Power in Latin America*, No. 73 (July 2001), p. 16.

63. "Renewable Energy Enters Latin America Supply Mix," *Financial Times: Power in Latin America*, No. 75 (September 2001), pp. 9-12.

64. "Rural Areas Get Electricity Aid From the IDB," *Financial Times: Power in Latin America*, No. 73 (July 2001), pp. 20-21.

65. "Renewable Energy Enters Latin America Supply Mix," *Financial Times: Power in Latin America*, No. 75 (September 2001), pp. 9-12.

66. Energy Information Administration, "Country Analysis Brief: Azerbaijan," web site www.eia.doe.gov (May 2001).

67. Energy Information Administration, "Country Analysis Brief: Georgia," web site www.eia.doe.gov (April 2001).

68. "Today in Brief: FSU: Ukraine: Renewable Energy Bill Passed," *World Markets Online*, web site www.worldmarketsonline.com (July 9, 2001).

69. "Capital LTD Intends To Acquire Kazakhstan Renewables Developer," *Solar & Renewable Energy Outlook*, Vol. 27, No. 16 (August 15, 2001), p. 187.

70. Energy Information Administration, "Country Analysis Brief: Balkans Region," web site www.eia.doe.gov (July 2001).

71. "Koncar Signs Hydro Upgrade Deals," *Financial Times: Power in East Europe*, No. 63/64 (August 6, 2001), p. 11.

72. "Koncar To Develop Hydro With Bosnia's EP HZ HB," *Financial Times: Power in East Europe*, No. 63/64 (August 6, 2001), p. 12.

73. Energy Information Administration, "Country Analysis Briefs: Romania," web site www.eia.doe.gov (November 2000).

74. "Electricity in Brief," *Financial Times: East European Energy Report*, No. 117 (June 2001), p. 28.

75. "Eon Hungaria Moves into Wind Power," *Financial Times: East European Energy Report*, No. 120 (September 2001), pp. 23-24.

76. "Energy Sector Analysis: Kenya: Financiers Approve Hydro Project," *World Markets OnLine*, web site www.worldmarketsonline.com (June 20, 2001).

77. G. Alaran, "Energy Sector Analysis: Uganda: Nile Power Project Divides Ugandans," *World Markets Online*, web site www.worldmarketsonline.com (August 15, 2001).

78. "Energy Sector Analysis: Senegal: Manatali Hydro Project To Supply Three Countries by 2002," *World Markets Online*, wen site www.worldmarketsonline.com (August 1, 2001).

79. P. Bosshard, "An Act of Economic and Environmental Nonsense," International River Network, web site www.irn.org (March 1999).

80. "Energy Sector Analysis: Zambia: Tenders for Itezhi-Tezhi Hydro Power Project Ready in July," *World Markets Online*, web site www.worldmarketsonline.com (June 21, 2001).

81. "Energy Sector Analysis: Mozambique: Mepanda Dam Gets Favourable Environmental Report," *World Markets Online*, web site www.worldmarketsonline.com (April 24, 2001).

82. "Energy Sector Analysis: Sudan: Arab States Pledge Financial Assistance for Hydroelectric Plant," *World Markets Online*, web site www.worldmarketsonline.com (August 15, 2001).

83. "Energy Sector Analysis: Egypt: Zafrana Wind Farm Project Moves Forward," *World Markets Online*, web site www.worldmarketsonline.com (March 1, 2001); and American Wind Energy Association, "Global Wind Energy Market Report: Wind Energy Growth Was Steady in 2000; Outlook for 2001 Is Bright," press release (May 2001), web site www.awea.org/faq/global200.html.

84. Energy Information Administration, "Country Analysis Briefs: Turkey," web site www.eia.doe.gov (July 2001).

85. "Hewitt Consults on Controversial Dam," *BBC News Online*, web site www.bbc.co.uk (July 3, 2001).

86. International River Network, "Beyond Big Dams: An NGO Guide to the WCD," web site www.irn.org (2000).

87. "Turkey: Disputed Dam Loses Builder," *The New York Times* (November 14, 2001), p. A6.

88. R. Evans and D. Hencke, "Anger at Plea for Dam Funds," *The Guardian* (July 12, 2001), p. 1.1.

89. "Turkish State Hydraulic Works Signs Deal for Hydroelectric Power Plant," *Solar & Renewable Energy Outlook*, Vol. 27, No. 20 (October 15, 2001), p. 237.

Electricity

Electricity consumption nearly doubles in the IEO2002 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 2002* (*IEO2002*) reference case, worldwide electricity consumption is projected to increase at an average annual rate of 2.7 percent from 1999 to 2020 (Table 20 and Figure 74). The most rapid growth in electricity use is projected for the developing world, particularly developing Asia, where electricity consumption is expected to increase by 4.5 percent per year over the forecast horizon. Robust economic growth in developing Asia is expected to lead to increased demand for electricity to run newly purchased home appliances, such as air conditioners, refrigerators, stoves, space heaters, and water heaters. By 2020, developing Asia is expected to consume more than twice as much electricity as it did in 1999. China's electricity consumption alone is projected to triple, growing by an average of 5.5 percent per year over the forecast period.

Similarly, in Central and South America, high rates of economic growth are expected to improve standards of living and increase the demand for electricity for homes, businesses, and industry. The expected growth rate for electricity use in Central and South America is 3.9 percent per year between 1999 and 2020. For Brazil, the region's largest economy and largest consumer of electricity, electricity use is projected to increase by 3.6 percent per year, with increasing efforts to bring electrification to rural populations that have previously 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 1.9 percent per year—a considerably lower rate than has been seen in the past. 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.

There have been two important developments in the electricity sector in recent years that may affect the way the industry works in the future. The first is the increasing role of foreign direct investment in the developing regions of the world. Greater access to foreign investment in the electricity sector has allowed developing nations to construct the infrastructure needed for substantial increases in access to electricity, a particular problem for many developing nations.

A second important component of the electric industry's evolution over the past several years is electricity reform. Many developing countries have implemented reforms to the rules governing electricity generation and

Table 20. World Net Electricity Consumption by Region, 1990-2020
(Billion Kilowatthours)

Region	History		Projections				
	1990	1999	2005	2010	2015	2020	Average Annual Percent Change, 1999-2020
Industrialized Countries	**6,385**	**7,517**	**8,620**	**9,446**	**10,281**	**11,151**	**1.9**
United States	2,817	3,236	3,793	4,170	4,556	4,916	2.0
EE/FSU	**1,906**	**1,452**	**1,651**	**1,807**	**2,006**	**2,173**	**1.9**
Developing Countries	**2,258**	**3,863**	**4,912**	**6,127**	**7,548**	**9,082**	**4.2**
Developing Asia	1,259	2,319	3,090	3,900	4,819	5,858	4.5
China	551	1,084	1,523	2,031	2,631	3,349	5.5
India	257	424	537	649	784	923	3.8
South Korea	93	233	309	348	392	429	3.0
Other Developing Asia	357	578	724	872	1,012	1,157	3.4
Central and South America	449	684	788	988	1,249	1,517	3.9
Total World	**10,549**	**12,833**	**15,182**	**17,380**	**19,835**	**22,407**	**2.7**

Note: EE/FSU = Eastern Europe and the former Soviet Union.
Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

distribution in an effort to secure the foreign direct investment they need to modernize and improve the electricity infrastructure. In industrialized countries, many nations have undertaken electricity reforms to introduce greater competition in domestic markets in an effort to reduce the costs of electricity to consumers. These two factors are driving changes within the electricity sector and are expected to have a profound role on the development of the industry over the next two decades.

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 (Figure 75). 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 the Iranian Revolution of 1979, the use of oil for electricity generation has been slowing since the mid-1970s.

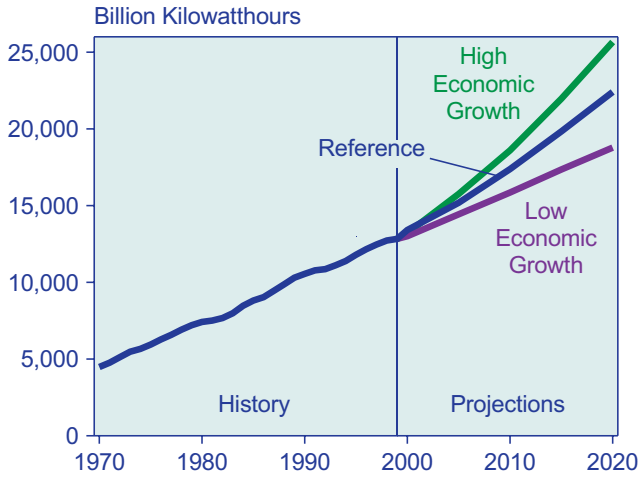
In the *IEO2002* reference case, continued increases in the use of natural gas for electricity generation are expected worldwide. Coal is projected to continue to retain the largest market share of electricity generation, but its importance is expected to be diminished somewhat by the rise in natural 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 more than 50 percent over the next 20 years, but their share of total electricity generation is projected to remain near the current level of 20 percent.

Natural Gas

Electricity markets of the future are expected to rely increasingly on natural-gas-fired generation. This trend is evident throughout the world, as industrialized nations are intent on using combined-cycle gas turbines, which generally are cheaper to construct and more efficient to operate than other fossil-fuel-fired generation technologies. Natural gas is also seen as a cleaner fuel than other fossil fuels. Worldwide, natural gas use for electricity generation is projected to double over the forecast period (Table 21), as technologies for 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 regions like Central and South America, where heavy reliance on hydroelectric power has led to shortages and blackouts when reservoirs are low.

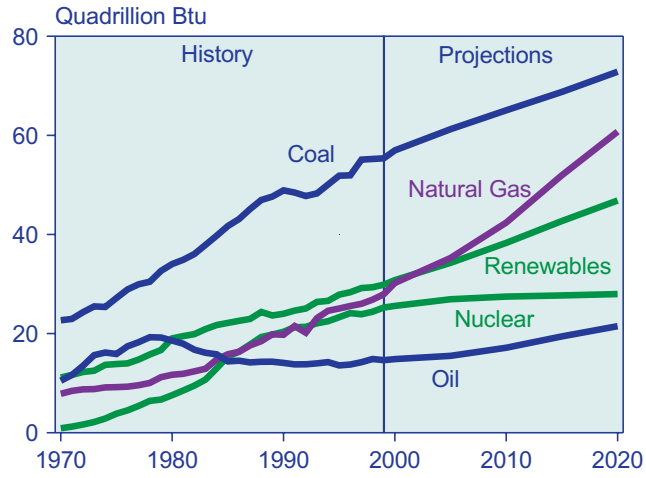
The former Soviet Union (FSU) accounted for more than one-third of natural gas use for electricity generation worldwide in 1999, and natural gas provided 51 percent of the energy used for electricity generation in the FSU. By 2020, natural gas is projected to account for 58 percent of the electricity generation market in the FSU. Relying increasingly on imports from Russia, the nations of Eastern Europe are also expected to increase

Figure 74. World Net Electricity Consumption in Three Cases, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

Figure 75. World Energy Use for Electricity Generation, 1970-2020



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

their reliance on natural gas for electricity generation, from 10 percent in 1999 to 21 percent in 2020.

Natural gas use in the electricity generation sector is also expected to grow rapidly in North America and Western Europe. In the United States the natural gas share of the electricity fuel market is expected to double from 15 percent in 1999 to 32 percent in 2020, and in Canada the gas share is expected to grow from 3 percent in 1999 to 11 percent in 2020. The movement toward natural gas is expected to be accelerated by reduced reliance on nuclear power. In addition, Canadian exports are expected to provide a growing supply of natural gas to U.S. generators.

Western Europe is expected to see its use of natural gas double over the forecast period. In 1999 natural gas held a 14-percent share of the electricity fuel market in Western Europe. That share is projected to grow to 28 percent in 2020 as Western European nations reduce their reliance on nuclear power and coal. After the oil crisis of 1973, European nations (as in the United States) actively discouraged the use of natural gas for electricity generation 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. As a result, the natural gas share of electricity generation increased rapidly.

In Central and South America natural gas accounted for 11 percent of the electricity fuel market in 1999. Its share is projected to grow to 32 percent in 2020. 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

Table 21. World Energy Consumption for Electricity Generation by Region and Fuel, 1995-2020
(Quadrillion Btu)

Region and Fuel	History		Projections			
	1995	1999	2005	2010	2015	2020
Industrialized	**77.1**	**83.8**	**91.4**	**97.5**	**104.4**	**110.5**
Oil	5.7	6.5	5.6	5.6	6.0	6.5
Natural Gas	9.7	11.6	15.6	18.1	22.8	26.6
Coal	27.7	29.6	32.3	34.1	35.0	35.9
Nuclear	19.4	20.6	21.1	21.1	20.8	20.3
Renewables	14.7	15.4	16.9	18.5	19.8	21.1
EE/FSU	**26.4**	**23.8**	**26.2**	**27.5**	**29.3**	**31.1**
Oil	2.8	2.4	3.2	3.7	4.4	4.9
Natural Gas	10.6	10.3	11.2	12.5	14.2	15.9
Coal	7.4	5.4	5.5	4.8	4.0	3.6
Nuclear	2.5	2.7	3.2	3.0	3.0	2.8
Renewables	3.1	3.0	3.2	3.4	3.7	4.1
Developing	**38.1**	**45.4**	**55.5**	**65.2**	**76.6**	**88.1**
Oil	5.1	5.7	6.8	7.9	9.0	10.2
Natural Gas	4.8	6.1	8.5	11.8	15.1	18.3
Coal	16.8	20.3	23.5	26.1	29.7	33.3
Nuclear	1.4	1.9	2.6	3.3	3.9	4.9
Renewables	10.1	11.5	14.1	16.1	18.9	21.4
Total World	**141.7**	**153.1**	**173.1**	**190.2**	**210.4**	**229.7**
Oil	13.6	14.6	15.5	17.1	19.4	21.5
Natural Gas	25.1	28.0	35.3	42.4	52.0	60.8
Coal	51.9	55.4	61.2	65.0	68.7	72.8
Nuclear	23.3	25.3	26.9	27.5	27.7	28.0
Renewables	27.9	29.9	34.1	38.1	42.5	46.6

Note: EE/FSU = Eastern Europe and the former Soviet Union.
Sources: **History:** Derived from Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

gas as a means of diversifying their electricity supplies. A continent-wide natural gas pipeline system is emerging 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. Japan alone accounts for 26 percent of natural gas consumption in Asia, and almost all the natural gas consumed in Japan is liquefied natural gas (LNG). Japan is expected to increase its dependence on natural gas from 21 percent of the electricity fuels market in 1999 to 23 percent in 2020.

Coal

In 2020, coal is expected to account for 32 percent of the world's electricity fuel market, slightly lower than its 36-percent share in 1999. The United States accounted for 35 percent of all coal use for electricity generation in 1999 and developing Asia 31 percent. In the *IEO2002* forecast, the coal share of U.S. electricity generation is expected to decline to 46 percent in 2020 from 51 percent in 1999; and in developing Asia the coal share is projected to decline to 51 percent in 2020 from 62 percent in 1999. Although coal remains a relatively inexpensive fuel for electricity production, natural gas is generally regarded as being environmentally superior, and the improving economics of natural gas generation technology also suggest that natural gas will gain market share.

Reliance on coal for electricity generation is also expected to be reduced in other regions. In Western Europe, for example, coal accounted for 23 percent of the electricity fuel market in 1999 but is projected to have only a 15-percent share in 2020. Similarly, in Eastern Europe and the FSU (EE/FSU), coal's 23-percent share of the electricity fuel market in 1999 is projected to fall to 11 percent by 2020. For years, massive state subsidies were all that kept many Western and Eastern European coal mines in operation. In many cases, the subsidies were underwritten by electricity consumers. Europe's dependence on coal as a source of electric power generation has waned with the gradual diminution of state subsidies.

Nuclear Power

The nuclear share of energy use for electricity production is also expected to decline in many regions of the world as a result of operational safety concerns, waste disposal issues, concerns about nuclear arms proliferation, and the economics of nuclear power. In 2020, nuclear power is projected to capture 12 percent of the electricity fuels market worldwide, down from 16 percent in 1999. In many nations, the projected move away from nuclear power has slowed in the past several years. In the United States, for example, several nuclear utilities have been granted license extensions for their nuclear power reactors. Moreover, in the United States and the United Kingdom, several nuclear utilities have announced their intentions to build new units in the future.

In the United States, the nuclear share is projected to drop from 20 percent of the electricity fuel market in 1999 (second behind coal) to 13 percent in 2020. In Canada, where the nuclear share of the market has been declining since 1984, its 14-percent share in 1999 is projected to remain stable. In Western Europe, the nuclear share of the electricity fuel market is projected to fall from 35 percent in 1999 to 24 percent in 2020—more than any other energy source. (Finland and France are alone among Western Europe's nuclear power producers in remaining committed to expansion of their nuclear power programs.)

In Japan, nuclear power accounted for 33 percent of the energy used for electricity generation in 1999. That share is expected to rise to 37 percent by 2020 in the *IEO2002* forecast. In the EE/FSU region, the nuclear share is projected to decline from 12 percent in 1999 to 9 percent in 2020.

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 2020. Among South American nations, only Argentina and Brazil were nuclear power producers in 1999. In Africa, only South Africa generated electricity from nuclear power in 1999. There are no nuclear power plants in operation in the Middle East, although one is 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 6 to 8 percent from 1999 through 2020. China is expected to account for most of the region's nuclear power capacity additions.

Hydroelectricity and Other Renewables

Renewable energy, particularly hydropower, accounted for 20 percent of the world's energy use for electricity generation in 1999, where it is expected to remain in 2020. Of the world's consumption of renewable energy for electricity production in 1999, the United States and Canada together accounted for almost 26 percent of the total, Western Europe 19 percent, and Central and South America 19 percent (despite consuming just 5 percent of the world's electricity).

In 1999, renewables accounted for 11 percent of electricity production in the United States and 62 percent in Canada, both nations where hydroelectric power has

been extensively developed. The renewable shares of electricity generation are expected to decline in both countries over the forecast period, the U.S. share to 9 percent and the Canadian share to 54 percent. 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 for energy fuels assumed in the *IEO2002* reference case.

Hydroelectricity is most widely used for electricity generation in Central and South America, and renewables accounted for 75 percent of the region's electricity fuel market in 1999. However, 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. The renewable share of electricity generation in Central and South America is expected to decline to 55 percent by 2020 as the region works to diversify its electricity fuel mix.

Most of Western Europe's renewable energy consumption consists of hydroelectricity. Renewables in total accounted for 22 percent of the region's electricity market, and their share is expected to increase to 26 percent in 2020. 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 16 percent of its electricity production in 1999, and that share is expected to grow to 19 percent by 2020.

Oil

The role of oil in the world's electricity generation market has been on the decline since the second oil price shock that started in 1979. Oil accounted for 23 percent of electricity fuel use in 1977, but in 1999 its share was under 10 percent. Energy security concerns, as well as environmental considerations, have led most nations to reduce their use of oil for electricity generation. However, in regions where oil continues to hold a significant share of the generation fuel market, such as the FSU and the Middle East, it is expected to continue to play a relatively prominent role. As a result, the oil share of world energy use for electricity production is projected to slip only slightly, to 9 percent in 2020.

Developing Asia accounted for 17 percent of the world's consumption of oil for electricity generation in 1999, when 9 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 2020. In the petroleum-rich Middle East, oil supplied 35 percent of the energy used for electricity generation in 1999, and its share is projected to fall to 24 percent in 2020, as these countries continue to build their reliance on natural-gas-fired generation.

Project Finance in the Developing World

Developing countries are expected to see their electricity consumption grow at a 4.2-percent annual rate through 2020 (Table 20). In order to achieve such growth, billions of dollars in capital investment will need to be raised.

There are numerous methods available for the financing of power projects in developing countries (for example, see box on page 132). These methods allow for various levels of participation and control by private (and sometimes foreign) investors. They range from management and operations contracts to greenfield projects to full divestitures:

- Management and operation contracts involve an outside private entity managing but not owning a public entity—often for a specified period of time. They involve the state ceding the least amount of control to private enterprise.
- Greenfield projects involve the construction of new power plants by private investors or by public-private ventures. They may be build-own-operate (BOO), build-operate-transfer (BOT), or build-lease-own (BLO) agreements [***1***].
- Divestitures fall on the other end of the spectrum from management contracts, allowing for a much deeper level of involvement as the private firm takes a substantial equity stake in what was a domestic (and sometimes publicly owned) enterprise.

The most common forms of financing are debt and equity. In the case of power projects, debt usually consists of commercial bank loans or bond issuances. Equity, on the other hand, usually consists of taking stock or ownership in the project or company. One instrument that blends the qualities of debt and equity is a subordinated loan, which is given "repayment priority over equity capital, but not over commercial loans or other senior debt" [***2***].

Another concern for investors in developing countries involves the claim that various loans and bonds have on the assets and cash flows of the project developer in the event of a default. Financing has ranged from traditional corporate finance to the now popular project finance. Traditional corporate lending usually involves the power project being backed by the sponsor's balance

Micro-Credit for Micro-Electricity in Bangladesh

A major impediment to providing much of the developing world with access to electricity has been the inability to obtain financing for the necessary infrastructure. The Grameen Bank (Village Bank) is a nongovernmental organization that has been providing micro-credit loans[a] to rural inhabitants of Bangladeshi villages since 1976. The loans are used to finance small business activities, such as raising chickens, producing handicrafts, and operating cellular phone centers. They have been extremely successful in improving the lives of the rural poor in Bangladesh, and the concept has been replicated in many other countries of the world, including the United States. In 1996, the Grameen Bank established a subsidiary called Grameen Shakti (Village Power), with the intent of providing renewables-based electrification opportunities for rural populations.

The concept of the Village Power program is simple: to extend micro-credit opportunities that would allow rural households and commercial establishments the opportunity to finance renewable energy systems. For electricity consumers in developing countries, a typical 50-watt photovoltaic system costs about $450,[b] including photovoltaic panels, switches, outlets, wiring, a charge controller, end-use devices, and a battery. (On rainy days or in overcast weather the battery can provide backup power for a few days). In Bangladesh, 50-watt systems provide enough power to operate four 6-watt compact fluorescent lights, a black-and-white television, or a few small fans.[c] This amounts to a significant amount of power for most rural households in Bangladesh, which currently have few existing means of connecting to power providers. Bangladeshi villagers either do without electricity (which is the prevalent option for most) or, if they are wealthy enough to afford it, purchase 2 or 3 car batteries, which must then be transported several miles by hand to the nearest market for periodic recharging.

Traditionally, rural lenders in countries such as Bangladesh have charged poor local villagers and farmers a steep premium over the interest rates charged by more established financial institutions operating in urban areas. Rates charged to villagers in Bangladesh have exceeded 150 percent.[d] Part of the premium could be justified on the basis of the *real* creditworthiness of the two borrowers; part could also be ascribed to the relatively large transaction costs that accompany small-scale lending. However, part can also be attributed to "knowledge asymmetry," which prevents market penetration by outsiders into the business of lending to rural villagers and provides justification for local monopoly. Other potential lenders include indigenous commercial banks and even foreign financial intermediaries, but they lack the intimate knowledge that local moneylenders have about the local business climate, such as which individuals have the industriousness and thrift habits that would make them desirable clients. These habits could easily be well known to local lenders living in the community but a mystery to outsiders.[e]

The Grameen Bank managed to surmount this hurdle in several interesting ways. In order to qualify for a Grameen Bank loan, potential borrowers must form a group. Peer pressure is thus exerted to make borrowers comply with the agreed-upon repayment arrangement, as any noncompliance is made public to the group. Family members are excluded from joining the same group. Interestingly, 90 percent of loan recipients are female.[f]

Small-scale photovoltaic systems have been installed in many places around the world. Grameen Shakti's innovation (at least in Bangladesh) was in arranging a marriage between micro-credit and renewable micro-energy. The $450 cost of a photovoltaic system is an expensive proposition in a country where annual

(continued on page 133)

[a]Micro-credit loans are small loans (average amounts are about $100) that are provided to the poorest of poor in rural areas. The loans are provided in lieu of a business plan that the recipient has to present to show how the loan would be utilized. More than 90 percent of Grameen's borrowers are women. Loans are made to individual women, who help each other with repayment issues.

[b]Personal communication with Mr. Dipal Barua, Managing Director, Grameen Shakti, October 23, 2001.

[c]Dipal Barua, "Energy's Role in Rural Income Generation: The Grameen Strategy," Presentation at Village Power Workshop 1998 (Washington, DC, October 1998).

[d]H.R. Varian, "Economic Scene: In a Market for Lending in Developing Nations, a Bangladesh Bank Relies on Peer Pressure for Collateral," *The New York Times* (November 22, 2001), p. C2.

[e]One seminal study, which among other things, analyzed the causes for the wide interest gap charged to Indian villagers relative to rates charged by large banks in central cities, attributed this gap in part to the asymmetry in knowledge possessed by traditional rural moneylenders over outsider financial intermediaries, thereby preventing outsiders from penetrating into their territory. See G.A. Akerlof, "The Market for Lemons: Quality Uncertainty and the Market Mechanism," *Quarterly Journal of Economics*, Vol. 94, No. 3 (August, 1970), pp. 488-500.

[f]H.R. Varian, "Economic Scene: In a Market for Lending in Developing Nations, a Bangladesh Bank Relies on Peer Pressure for Collateral," *The New York Times* (November 22, 2001), p. C2.

sheet. In contrast, project finance separates the project's balance sheets from those of the sponsor company [*3*]. In this form of financing, only the revenues from the project are slated to pay the equity holders and creditors; in other words, the project investors can only lay claim to the project's cash flows and assets and not the cash flows and assets of the sponsor's other operations. This is known as nonrecourse financing. Most projects in developing countries combine both forms of backing in what are called limited recourse projects. Limited recourse projects might involve some additional backing, such as a pre-completion during the project's construction period, or a government or sponsor guarantee [*4*]. Whereas traditional corporate debt is beneficial in that it allows borrowers to pay lower rates of interest, nonrecourse and limited recourse financing expose investors to less risk.

The selected project financing technique depends heavily on the creditworthiness of the country where the investment is taking place. Legal systems, economic and financial environments, and political stability are some of the factors that determine a nation's creditworthiness. The most obvious method for repayment of the costs of a power plant would be through the cash flow from the operations of the plant. However, many developing countries are plagued by theft of electricity or tariff rates that cannot support the cost of the plant. For riskier projects, state Export Credit Agencies (ECAs) often play a role in providing loans, making guarantees to financiers of the project, or acting as an insurance facility. Developing countries are also recipients of major funding packages from multilateral and bilateral agencies or credit facilities, which have a function similar to that of ECAs.

Among world regions both Asia and Latin America stand out as major targets of private investment in electricity during the 1990s. During the 1990s, Latin America's power sector attracted $78 billion in private investment (Figure 76). Seventy-one percent of that investment consisted of equity (Figure 77). Latin American countries have been pioneers in privatization, not only in the power sector but also in pension systems, telecommunications, etc. Among Latin American nations, Chile has been a leader in privatization and was the first to privatize and unbundle electricity generation, transmission, and distribution within the electricity industry. Chile was also a trailblazer in allowing foreign investment in its domestic electricity sector. Currently, Chilean electricity companies are investing in the power sectors of other Latin American countries. Argentina followed Chile's reform with a wholesale privatization and restructuring of the nation's electricity sector. In some Latin American nations, all segments of the electricity industry have been opened to private investment from

Micro-Credit for Micro-Electricity in Bangladesh (Continued)

per capita income is about half that. To provide villagers access to the necessary capital, the micro-finance aspect of Village Power involves a loan package under which households have the option of making a 15-percent down payment and paying the remainder over a 2-year period at an annual interest rate of about 12 percent. Grameen Shakti provides all the necessary equipment and meets service needs for one year—in effect, acting as a mini-utility.

There are a number of energy applications to which micro-credit financing mechanisms have been applied:

- Operation of a soldering iron to repair radios and televisions
- Residential and commercial lighting, which allows children to study at night and laborers to work past sunset
- Cellular phone charging and "renting out" phone services to allow surrounding villagers to communicate with the outside world
- Biodigesters to produce methane gas for cooking and fertilizer.

To date, the Grameen Shakti photovoltaic program in Bangladesh has been successful. An interesting aspect of the program has been the creativity that has been shown by borrowers. As loan recipients have had the opportunity to experience the benefits of renewable energy systems, they have developed innovative applications for the energy, which have helped sustain the micro-energy program in Bangladesh. For example, one loan recipient installed a solar-based mini-grid to supply electricity to shops in the village market.

As of September 2001, Grameen Shakti had installed 5,800 photovoltaic systems representing 290 kilowatts of capacity.[g] In addition to continuing the sale of photovoltaic systems for residential lighting applications, the organization plans to expand the use of renewable energy systems to commercial activities that will generate income for villagers. It has installed and is successfully operating five solar-powered computer education centers at remote areas. Most importantly, however, the micro-credit loan programs have been able to improve the standard of living for many impoverished Bangladeshi without access to traditional electricity services or financial intermediaries.

[g]Personal communication with Mr. Dipal Barua, Managing Director, Grameen Shakti, October 23, 2001; and Grameen Shakti, "Programs: Photovoltaics (PV) Program," web site www.grameen-info.org/grameen/gshakti (September 10, 2001).

generation to transmission to distribution. Municipally owned, state-owned, and nationally owned utilities have been wholly privatized and, in some instances, sold to foreign investors.

On the other end of the spectrum, developing Asian countries have generally not engaged in deep power sector reform and typically have chosen to rely more on independent power providers (IPPs) that outsource to the public grids. In contrast to Latin America, Asia's electricity sector, which attracted a greater $93 billion in private investment between 1990 and 1999 (Figure 76), saw 72 percent of that investment directed to greenfield projects (Figure 77). Private-sector involvement generally has been limited to generation; transmission and distribution have traditionally been in the hands of the government. Private-sector participation in Asian electricity industries has focused on greenfield projects of IPPs, which bring in large amounts of new generation and foreign investment. This has sometimes led to serious problems, however, as the highly politicized issue of determining fair tariff rates discourages the ability to raise enough revenue to support the cost of generation without the aid of government subsidies. Recent controversial private electricity investments such as the Dabhol/Enron arrangement (see box on page 135) has led to some debate about the most suitable forms of privatization and financing for various regions.

World Electricity Deregulation

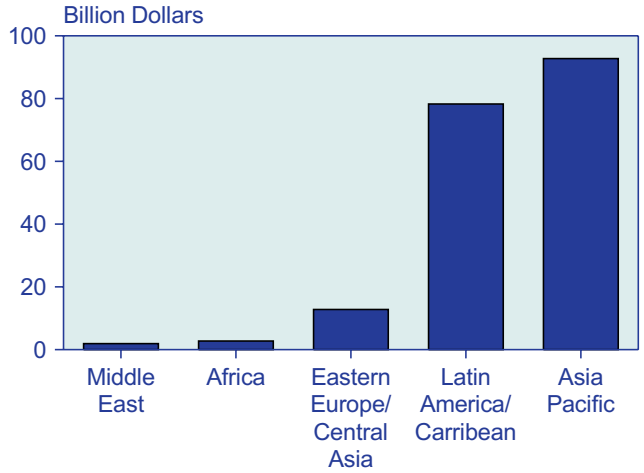
Recent efforts at electricity reform could be included as one of the most significant global energy developments of the past century. Since the mid-1990s, more than 30 countries or regions within countries have attempted significant electricity reform measures [***5***].

In those developed nations where electricity assets have been publicly owned, privatization (and its weaker cousin, corporatization[19]) has been a major element of reform. Many industrialized nations have also for the first time opened their doors to foreign investment. For the most part, however, electricity reform in the industrialized world has involved a restructuring of the industry along the lines of its different functions, as well as a rewriting of the rules under which participants in electricity markets operate. The restructurings and rule changes vary among countries, but several similarities stand out.

Recent efforts at electricity reform can be traced to developments that occurred more than two decades ago. The United States embarked on an opening up of its electricity market to new entrants with the passage of the Public Utilities Regulatory Policies Act of 1978. Countries such as Chile (which started its reform in 1982), New Zealand (1987), Norway (1991), and Argentina (1992) were also early reformers. However, the United Kingdom, which embarked on sweeping privatization and restructuring of its electricity sector beginning in 1989, was the pioneer for reforms elsewhere.

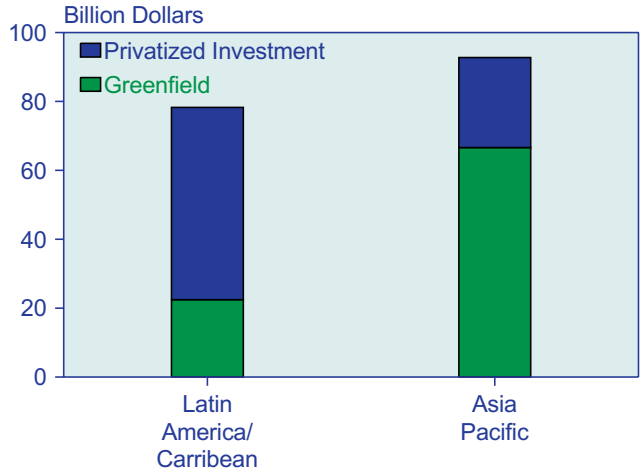
In countries with federalist forms of government, state or provincial governments have often led the way in electricity sector reform. In Australia, for instance, reforms in the state of Victoria predated national reforms. Similarly, in Canada, the province of Alberta (1996) was the first province to adopt electricity reform

Figure 76. Cumulative Private-Sector Investment in Electricity Among Developing Regions, 1990-2000



Source: Public Policy for the Private Sector, World Bank Data Base.

Figure 77. Cumulative Total Investment in Electricity Projects in Asia and Latin America, 1990-1999



Source: Public Policy for the Private Sector, World Bank Data Base.

[19]Corporatization maintains public ownership but allows management autonomy. The separation between the state and management of the entity is imposed in order to force the entity to behave more like a competitive business.

India's Dabhol Power Project

Domestic capital shortages in recent years have led some developing nations to open up their domestic electricity markets to foreign investors. In the early 1990s, a consortium led by U.S.-based Enron Corporation[a] began negotiations with the state government of Maharashtra in India for Enron to build an electricity generation plant near Dabhol, 180 miles south of Mumbai (formerly Bombay). The Maharashtra State Electricity Board (MSEB)[b] finalized an agreement that led to the creation of the Dabhol Power Corporation in June 1992. Since then, the project has progressed precariously, and serious contractual issues have arisen between Enron and the host state. Currently, the project is at a standstill.

Electricity reform in India began shortly before the Dabhol project was initiated. In 1991, a balance of payments crisis that followed a decade of economic isolationism prompted the Indian government to liberalize the nation's foreign investment policies. To attract foreign investment, India encouraged private-sector involvement in public-sector enterprises, including electricity generation. India's central government relaxed previously stringent measures in order to jump-start major power projects, known as the "fast track projects."[c]

Dabhol, the first of India's fast track projects, got off the ground with a memorandum of understanding between Enron and the MSEB in June 1992. The understanding called for the construction of a 2,015-megawatt power plant. The original power purchase agreement (PPA) between Enron and Dabhol was signed for the first of two phases in December 1993. In Phase I, imported distillate was to be used to fuel the new power plant while construction of a receiving terminal and regasification facility for liquefied natural gas (LNG) was being completed. In Phase II, the power plant would be fueled with natural gas from the LNG import terminal. The agreement required the MSEB to buy 90 percent of the plant's baseload generation at 7.5 cents per kilowatthour for 20 years after commissioning.[d] Both fuel price fluctuation risk and foreign exchange risk were assumed by the MSEB.

Concerns about the project were raised in 1995 when a new government represented by the Shiv Sena and the Bharatiya Janata Party (BJP) coalition party[e] came into office in Maharashtra after conducting a campaign marked by economic nationalism. A review committee, headed by Gopinath Munde, former deputy chief minister of Maharashtra, was formed to examine the PPA contract along with other parameters of the project. The committee's report raised concerns about the project's potential environmental damage, the fact that the initial contract negotiation lacked competitive bidding and public scrutiny, and the reasonableness of the project's capital costs. It also noted that the World Bank had recommended using the plant for peak load and had suggested that another fuel source, such as coal or naphtha, would be more suitable than natural gas.[f]

In June 1999, the Maharashtra government initiated the cancellation of the Dabhol project.[g] In response, Enron agreed to a renegotiated contract that called for, among other things, a new PPA that attempted to resolve a number of the review committee's concerns. The total capacity of both project phases was increased (from 695 megawatts to 826 megawatts in Phase I and from 1,320 megawatts to 1,624 megawatts in Phase II), with the additional generating capacity to be provided by Enron at no additional cost. The power purchase charge—although still subject to fuel price and exchange rate fluctuations—was lowered from 7.5 cents to 6.0 cents kilowatthour. The capital cost charge was lowered by excluding the cost of the regasification facility, which was to be included instead in the cost of the fuel. There was a reduction in the foreign exchange component of payments to Enron by 400 billion rupee (about $8.4 billion), and the MSEB was given an equity stake of 30 percent in the project. The project's fuel was switched to cheaper domestic naphtha for Phase I until commissioning of Phase II. More environmental provisions were agreed to, and employment was to be provided for one member of each family displaced by the project's construction site.[h]

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[a]Enron's partners included Bechtel Enterprises Holdings, Inc., and GE Capital Structured Finance Group, which were equity holders; various domestic and international financial institutions also supported the project through loans.

[b]SEBs are state electricity boards which are in charge of providing generation, transmission, and distribution by coordinating with both public and private players involved both at the state and central level.

[c]Fast track projects were power projects of at least 1000-megawatt capacity and were given clearance much faster than normal power projects as a means of attracting foreign investment.

[d]K.S. Parikh, "Thinking Through the Enron Issue," *Economic and Political Weekly* (April 28, 2001). This charge included the capital charge, operating and fuel charges.

[e]The Congress Party was in office when the original proceedings occurred, and it was pro-liberalization. Coalition parties often are formed among India's many diverse political parties.

[f]"India: Dabhol Power Project," web site http://altindia.net/enron/Home_files/WBnote.htm (April 30, 1993).

[g]"Munde Sub-Committee Report," web site www.hrw.org/reports/1999/enron/enron-b.htm.

measures. In the United States, the State of California (1998) had been at the forefront of State-initiated electricity reforms; however, the State has now begun to "re-regulate."

Much of the electricity reform undertaken in various countries has been motivated by similar issues, including the following:

- Technological developments, particularly those related to the growing efficiency of natural gas turbines
- Investment shortages, particularly among developing countries
- High electricity prices
- A rethinking of the notion of electricity supply as a natural monopoly.

Technological Developments

For most of the last century, reductions in the cost of electricity generation were achieved through the building of larger and larger generators, which in essence supported the view that electricity generation was a natural monopoly.[20] In recent years, however, developments in natural gas technology have reversed that trend, allowing maximum efficiencies to be realized at lower and lower generation capacity levels. Almost all new generation capacity added in the United States currently is gas-fired. Gas-fired capacity offers several technological advantages over its alternatives. and—at all but the lowest interest rates—is more competitive than coal. Today, a state-of-the-art combined-cycle natural gas unit is more efficient than coal or nuclear units. Gas-fired plants also have shorter startup times. The time needed to build a natural-gas-fired generation unit averages 2 to 3 years, compared with 3 to 5 years for coal

India's Dabhol Power Project (Continued)

The new PPA became legally binding in August 1996, and Phase I began operation in 1999. The new contract soon ran into trouble, however. In July 2000, the average price of power from the Dabhol project rose sharply, following a depreciation of the rupee against the U.S. dollar and an increase in natural gas prices from 1999 to 2000. Early in 2001, the MSEB defaulted on its November electricity bill. The bill was eventually paid by the MSEB with assistance from the state government, but Phase I of the project was shut down, and construction on Phase II was halted.

A new energy review committee, chaired by Madhav Godbole, former chairman of the MSEB, was established by the Maharashtra state government. The committee's mandate was to review the electricity situation and particular electricity projects, including Dabhol. The review committee submitted Part I of the report on April 10, 2001.[i] It concluded that the Dabhol Power Corporation was overcharging the MSEB in terms of the regasification facility, shipping and harbor costs, operating and maintenance costs, and fuel consumption. Several guidelines were recommended to reduce the tariff and liability of the project.

The project hit another obstacle when the parent corporation, Enron, after tumbling into a financial abyss, filed for bankruptcy in December 2001. Enron's share prices declined from $85 one year earlier to 26 cents by late 2001.[j] As a consequence, in December 2001, the Dabhol Power Corporation laid off 200 of its remaining employees. Many different approaches to the Dabhol project's financial difficulties are currently being entertained. Various entities that have been involved have stepped forward to offer possible solutions, including the World Bank and various other financial institutions, as well as external parties new to the scene, including domestic rivals Bombay Suburban Electric Supply and Tata Power Company, as well as other global energy giants that may seek to fill the role left vacant by Enron's apparent demise.

Whatever its eventual outcome, the drama of the Dabhol project has exposed some of the ills of India's electricity system. According to R.K. Pauchari, director of the Tata Energy Research Institute, electricity reform could add 1 to 2 percent to India's Gross Domestic Product "almost instantly," and although reform has occurred at different levels in a handful of states (Orissa, for example) widespread reform is still in the early stages.[k] The project has also exposed some of the difficulties foreign companies face in investing in countries currently making a transition toward freer market economies.

[h]J.W. Salacuse, "Renegotiating International Project Agreements," *Centre for Energy, Petroleum and Mineral Law and Policy Internet Journal*, web site www.dundee.ac.uk/cepmlp (August 2001).

[i]The report can be found at web site www.maharashtra.gov.in/english/energy/rerc.htm. Part II was published September 2001 and focuses mostly on the general sector reform.

[j]K.M. Kristof, "Bankruptcy of Energy Trader May Hurt Many," *Los Angeles Times* (December 3, 2001).

[k]"Red Tape and Blue Sparks: A Survey of India's Economy," *The Economist*, Vol. 359, No. 8224 (June 2, 2001), pp. 9-14.

[20]A natural monopoly is desirable in a situation where one firm can produce a given level of output at a lower total cost than can any combination of multiple firms.

plants. In many countries nuclear power plants, if still an option, would take even more time to construct than a coal-fired plant.

Natural gas plants are also more flexible. The maximum efficiency of a gas-fired power plant is achieved at a much smaller level of capacity than a coal-fired unit. This feature increases the attractiveness of natural-gas-fired units, because the size of a new natural gas plant being introduced can be adapted readily to various changes in demand, and it can be built closer to the location where those changes are taking place. For all these reasons, future new capacity additions no longer need to be the domain of large utilities, and indeed no longer need to be in the domain of utilities at all. In both the United States and the United Kingdom, the move to natural gas has done much to foster an independent power generation industry—an industry less subject to government regulation than are traditional utilities.

Investment Shortages in Developing Countries

In the developing world, a lack of access to capital has in many instances hindered investment in electricity infrastructure. As a result, many countries have opened their electricity sectors to more direct forms of investment from overseas. This has been particularly true in the case of countries that suffered most during the widespread debt crisis of the 1980s. In Latin America, where economic growth and investment languished throughout most of the period, the 1980s were know as the "lost decade." Moreover, during the 1980s, financial institutions, in particular commercial banks, incurred severe losses from loan defaults among developing nations, which may have had a limiting impact on the developing world's access to some world capital markets and may have driven developing countries to allow greater direct investment from abroad. Another reform measure, which was commonly employed by developing countries in Asia, was to open up domestic electricity sectors to greenfield investments by foreign sources.

High Electricity Prices

Electricity prices vary considerably across regions and countries. Some of the variation can be accounted for by the degree of access to relatively cheap forms of electricity. For instance, in Norway, which relies on relatively cheap hydropower for almost all its electricity, electricity prices typically have been relatively low by industrial world standards [***6***]. The same is true of the Pacific Northwest of the United States, where colossal dams, many of which were built during the 1930s, provide relatively cheap sources of electricity.

Regional and national electricity prices also vary considerably with the ownership structure of the industry and the degree of regulation. The resulting price differentials can have a significant effect on a region or area's degree of competitiveness. They can also affect real standards of living. Many high-cost electricity countries, provinces, and U.S. States were among the earliest reformers. For instance, in 1995 electricity prices in California were 43 percent higher than the U.S. average [***7***], and industrial electricity prices in Germany were 15 percent higher than in the Organization of Economic Cooperation and Development (OECD) as a whole (Table 22).

Monopoly Industry and Competitive Industry

Another aspect of electricity reform is a rethinking of the notion that electricity supply is a natural monopoly. The rethinking has focused mostly on the generation

Table 22. OECD Industrial Electricity Prices, 1990-2000
(1999 Dollars per Kilowatthour)

OECD Country	1990	1995	1999	2000
Australia	0.042	0.048		
Austria	0.053	0.060	0.056	
Belgium	0.054	0.055		
Canada	0.032			
Czech Republic	0.101	0.149	0.121	0.125
Denmark	0.041	0.046	0.053	0.054
Finland	0.038	0.045	0.042	0.041
France	0.046	0.046	0.040	0.039
Germany	0.071	0.071	0.052	
Greece	0.073	0.071	0.061	
Hungary	0.180	0.093	0.124	0.129
Ireland	0.059	0.064	0.059	0.056
Italy	0.082	0.097	0.093	0.117
Japan	0.091	0.103	0.101	
Korea	0.092	0.093	0.101	0.112
Mexico	0.074	0.059	0.069	0.079
Netherlands	0.044	0.059	0.061	0.068
New Zealand	0.036	0.040	0.038	0.035
Norway	0.023			
Poland	0.080	0.084	0.075	0.081
Portugal	0.135	0.148	0.116	0.113
Spain	0.091	0.083	0.067	
Sweden	0.033	0.029		
Switzerland	0.056	0.074	0.073	0.075
Turkey	0.144	0.156	0.170	0.187
United Kingdom	0.066	0.066	0.059	0.056
United States	0.047	0.047	0.044	0.045
OECD Europe	0.067	0.070	0.060	0.047
OECD Total	0.062	0.062	0.057	0.040

Notes: Prices were calculated using purchasing power parities. Some data points are missing, because not all countries provide price information of each year.

Source: International Energy Agency, *Energy Prices & Taxes, Quarterly Statistics* (Paris, France, Fourth Quarter 2001); and Energy Information Administration, *Monthly Energy Review*, DOE/EIA-0035 (Washington, DC, various issues).

side of the business and the relatively new business of electricity marketing. As mentioned earlier, with the economics of the industry changing in favor of smaller and smaller generation units, the opportunities for competition among different companies have grown. As a consequence, in many instances, countries have fully or partially liberated the generation side of the business from regulatory constraints while retaining regulation for the "wires" (transmission and distribution) side of the business. Competition in generation has also led to the creation of electricity pools, along with various hedging markets.

Global Electricity Reform

Various states, provinces, countries, and regions have undertaken efforts to reform their electricity sectors over the past two decades or so. Some of the reform efforts bear similarities; some have been unique. In general, however, the different paths to reform have involved one or more of the following actions:

- Unbundling of electricity assets through divestiture, or a vertical separation of ownership, and/or control, of certain electricity assets in order to promote competition, particularly in generation
- Creation of electricity trading arrangements (pools)
- Creation of independent system operators (ISOs) and, in the United States, regional trading organizations (RTOs)
- Privatization of electricity assets through sale or public auction, or the corporatization of the governance of the assets
- Deregulation of electricity prices and the implementation of a more restrained (light-handed) form of regulation where regulation was retained
- Open access to the grid
- Opening up of domestic electricity assets to foreign investment
- Retail competition.

Unbundling

Unbundling of electricity operations generally involves one of two approaches: (1) a separation of ownership of the various forms of electricity supply, i.e., generation, transmission, distribution, and marketing; or (2) a separation of control of the various forms of electricity supply. There are several motivations behind unbundling. One is to separate the potentially competitive elements of the business from those still bearing monopoly characteristics. Another is to offer various services with various price schedules, thus pricing various aspects of electricity supply at their costs of production, which adds greater transparency to electricity prices and enables consumers to make price comparisons.

In one form or another, most electricity reform around the globe has involved an unbundling of energy services. Several nations have attempted to achieve this goal through a vertical separation of ownership of various segments of the electricity industry. In Australia, Argentina, the United Kingdom, and the United States, unbundling involved the breaking up of vertically integrated utilities along their separate lines of business, creating distinct and separate corporate entities. In New Zealand, most of Western Europe, and the Nordic countries (Denmark, Finland, Norway, and Sweden), unbundling has generally involved the separate pricing of various electricity services and sometimes instituting an accounting separation between the different segments of electricity supply.

The United Kingdom was the first country to divest generation from distribution and transmission, which it accomplished in 1990. In the United Kingdom, the former government-owned power company (which included generation, transmission, and distribution assets) was separated during privatization into two generation companies, along with a transmission company and 12 distribution companies. A similar separation was instituted in Australia. As part of its reform efforts, California required its three major vertically integrated utilities to shed half their generation assets, which were largely sold off to independent power producers.

Another means of instilling more competition in generation involved not the separation of ownership but the separation of control. For instance, New Zealand separated transmission from distribution (although both remained government owned) and created two state-owned electricity generation companies so that they could compete against each other. Similar accounting separations occurred in Finland, Germany, Ireland, Portugal, and Spain [***8***].

Electricity Pools

Another important element of electricity reform involves the development of wholesale electricity trading arrangements, or electricity pools. In the past, most electricity was sold in bilateral forward markets. Several efforts at reform have initiated the introduction of pools to electricity exchanges. In several instances, electricity pools have been quite volatile. This volatility can serve a purpose in some market structures (e.g., by reducing demand or signaling a need for greater investment), but in others it has led to unwanted swings in earnings and prices to consumers. In order to deal with these and other complexities, various market designs have been employed by various countries and various regions in creating their electricity pools. These have sometimes included a variety of different trading arrangements: real-time pricing, day-ahead pricing, forward markets, and various hedging tools, such as futures markets and contracts for differences markets.

Although no two pool arrangements are identical, several share some similarities. In some cases, participation in electricity pools has been made mandatory, as initially was the case in Australia and the United Kingdom, or non-mandatory, as is the case in New Zealand, Nord Pool, Spain, and the Pennsylvania-New Jersey-Maryland pool (PJM) [***9***]. In several instances, unregulated bilateral markets have operated side by side with the pools, as in the United Kingdom, New Zealand, and the Nordic countries, or have been discouraged, as was the case in California. In some cases, prices have been set beforehand (as in the United Kingdom and Nord Pool), or by estimated supply and demand. In other cases, prices have been set after the market has cleared (as in Australia and New Zealand) or by actual supply and demand [***10***].

An important issue in the development of electricity pools involves ownership and / or corporate governance and the relationship of the pool to the entities that generate, transmit, and distribute electricity. Although electricity pools have existed in the United States since the late 1960s, the United Kingdom was the first to create a nationwide electricity pool, which has been in operation since 1990. In many ways the structure of this pool was copied elsewhere. Initially, the UK electricity pool was operated by the privately held National Grid Company, which was also responsible for electricity transmission. In turn, the National Grid Company was initially owned by 12 regional distribution companies (which were forced to divest their shares in 1995, when the National Grid became a separate, privately held concern). Similar organizational structures emerged in Sweden and Norway, where both system operation and pool operations fell under one umbrella organization [***11***]. In other countries and regions, ownership and / or control of the transmission system was separated from ownership and / or control of the electricity pool. This was true in Victoria (Australia) and California, where separate power exchanges were created in order to separate operation of the transmission system from operation of the pool.

Various countries have taken other approaches to pool ownership. In Alberta, Canada, the pool is operated on a cooperative basis governed by a council of pool participants [***12***]. In Finland, the power exchange was initially owned by a Securities and Derivatives Exchange. In New Zealand, the wholesale market is owned by the government-owned generation utility, the Electricity Marketing Company (EMCO). The PJM power pool is owned by 10 primary members, which are vertically integrated utilities.

Another important element of electricity pools is the rules under which they operate. The UK Pool (as it was initially set up), in some ways set the framework for many pools to follow. In order to balance electricity supply and demand, the UK government instituted a power pool to act as a clearinghouse between suppliers of electricity (generators) and wholesale consumers of electricity (primarily the regional electricity distribution companies).

In the UK Power Pool, every day was broken up into 48 half-hour segments. The system manager forecast demand for each half-hour segment. Twenty-four hours in advance, generators submitted bids for the various levels of power they were willing to supply at various prices and for various periods, for each half-hour period of the following day. The system manager then ranked the bids from least to most expensive. The system manager also calculated the minimum amount of generating capacity needed to meet demand projections. A merit order dispatch schedule was created, with the cheapest generation units selected first and supply capped when enough generation units were selected into the system to provide sufficient generation capacity to supply one unit of energy over and above the demand forecast [***13***].

The Pool purchase price for all suppliers was set by the highest bid from the last generation facility needed to accommodate the last unit of demand. This balancing activity was an attempt to arrive at the electricity generation industry's marginal cost, or the system marginal price (SMP). The price actually paid to generators also included a financial incentive (capacity payment) for maintaining some additional (peak load) generation capacity in the event that demand exceeded the consumption forecasts. This merit order system of estimating a supply / demand equilibrium has been duplicated elsewhere. Argentina and California have adopted similar mechanisms to set market clearing prices.

In the United Kingdom, as a means of controlling price volatility, a hedging market developed. This market, called the contract for differences market (CfD), allowed for bilateral contracts to be negotiated between generators and consumers. In the CfD market, generators and electricity purchasers could hedge Pool prices by committing to a contract with an agreed-upon price (the strike price). The strike price, for instance, might be set at an average of expected daily Pool prices. If the strike price turned out to be higher than the daily average Pool price, then the generator paid the purchaser the difference. Conversely, if the strike price turned out to be lower than the daily average Pool price, the electricity purchaser reimbursed the generator for the difference. In reality, the CfD market used a variety of different hedging contracts. Contracts for differences were purely financial contracts. A contracts for differences market also emerged in Australia.

In early 2001, the United Kingdom shut down the Pool and embarked on a new form of electricity trading,

called the New Electricity Trading Arrangement (NETA). This was done because it was felt that the old pool arrangements failed to foster adequate competition. Even after the UK generation market was broken up during the mid-1990s, the Pool was still highly concentrated (Table 23). Devising trading arrangements suitable to a commodity with such unusual features as electricity has been a problem that has dogged deregulators in several countries, states, and provinces. In several ways, NETA comes closer to resembling Nord Pool than the old Pool of England and Wales. It allows for self-dispatch instead of giving the National Grid Company the role of scheduler and orderer. It also allows for firms to be paid the price they bid rather than the system marginal price. Further, NETA opens up the wholesale market to nongenerators, thus allowing commodity traders to participate in the market [***14***]. Unlike the old Pool, NETA does not include a capacity mechanism, which is currently the case for the Nord Pool, the California Pool, the Australian National Pool, and the New Zealand Pool [***15***].

The Nord Pool, which has been in operation since 1996, was the world's first international electricity commodity exchange. The Nord Pool evolved from an informal arrangement whereby Scandinavian nations had traded electricity for decades [***16***]. Currently, Denmark, Finland, Norway, and Sweden buy and sell electricity in the Nord Pool. The Nord Pool employs two markets, a day-ahead spot market, Elspot, and a financial market, Eltermin, for weekly contracts. The Eltermin market does not actually trade power. Rather, like the contracts for differences markets which emerged in the United Kingdom and Australia, Eltermin allows for a financial settlement between electricity buyers and sellers. Unlike the pools set up in California and the United Kingdom, the Nord Pool is a voluntary market that is accompanied by a great deal of bilateral trade. In 1998, Elspot and Eltermin accounted for only 20 percent of the total power sold in the Nordic market [***17***].

In 1995, Alberta passed its Electric Utilities Act (EUA), which led to the establishment of an electricity pool in 1996, the Alberta Power Pool, which was a non-profit corporation. Unlike in the United Kingdom, in Alberta electricity buyers and sellers could negotiate direct sales. However, the Alberta Power Pool initially restricted entry into the buy side of the market to entitled buyers, which were the incumbent utilities when the pool was formed [***18***]. In Alberta's pool, prices were not entirely competitive, in that generators were under rate-of-return regulation for their fixed costs. The EUA also established an ISO to manage Alberta's transmission network. In 1998, Alberta adopted amendments to the EUA that were intended to encourage further price competition by allowing independent power production and requiring incumbent utilities to undertake power purchasing arrangements with independent marketers [***19***].

Table 23. Levels of Horizontal Concentration in Selected Generation Markets, 1996 and 1998

Market	Market Share of Two Largest Generators	
	1996	1998
UK (England and Wales)	55	41
Nord Pool	40	35
Australia (National Electricity Market)	40	36
New Zealand	90	53

Source: International Energy Agency, *Competition in Electricity Markets* (Paris, France, February 2001), p. 35.

In setting about electricity reform, California borrowed several elements from the UK model. For example, California's electricity reform required all sales to be conducted through a daily pool [***20***]. In the California Power Exchange, the pool price was set as follows: the California Power Exchange created an electricity supply and demand curve by combining all generator supply bids with all consumer demand bids. The clearing price—the price paid to the generators by the suppliers—was determined by the intersection of the supply and demand curves. This is similar to the pricing scheme initially employed in the United Kingdom, except that in the UK Pool demand was estimated by the National Grid Company. What distinguishes the California exchange from the UK Pool is the separation of the California Independent System Operator (CAISO) from the Power Exchange (PX). Moreover, California reforms did not provide pool participants with the hedging opportunities that the contracts for differences market provided in the United Kingdom and Australia, or the Eltermin market provided Nordic country participants.

Independent System Operators and Regional Transmission Organizations

ISOs have been developed in several states, countries, and provinces. In most cases, the ISO's function is to manage the grid and provide support to regional system operators. There are a number of forms an ISO can take, and there is an ongoing debate as to which is superior. One is a Transco, which is an independent system operator that both owns and operates the grid. Although Transcos may be profit or nonprofit enterprises, they are independent of system sellers and buyers. The National Grid Company in England and Wales is an example of a for-profit Transco [***21***].

In some cases, as mentioned in the above discussion of the UK Pool, the ISO and the pool have been one in the same, as in the case of the National Grid Company, which manages both the grid and the wholesale electricity market. Another form of ISO is the one operating in

California. CAISO is a nonprofit ISO that manages the grid but also allows for a separate power exchange, the California (CAL PX). Ownership of the transmission lines remained with the three major utilities.

Australia, New Zealand, Spain, the United Kingdom, and the Nordic countries have opted for the full separation of the grid from the generation of electricity. In the United Kingdom, Finland, Sweden, and Norway, the grid companies are under separate ownership from generation companies. In California, Spain, and the Netherlands, generators own the grid, but it operates independently from them [***22***]. Argentina created an ISO that was owned by the generation, transmission, and distribution companies [***23***].

Congestion management is a major concern of the newly created ISOs. Congestion management in California was based on a system of zonal pricing, similar to that used in Australia, which differs from the "postage stamp" rates[21] that are insensitive to congestion (and distance) operating in Alberta, Finland, Norway, the United Kingdom, and Sweden [***24***]. In contrast, Argentina, Chile, New Zealand, the PJM, and the New York ISO have opted for zonal pricing systems, which are most sensitive to congestion and distance traveled.

In the United States, current efforts at electricity reform have focused on improving the efficiency of the nation's transmission network. The transmission system in the United States is not a nationwide operation but rather a mixture of balkanized regional arrangements that result in lost trading opportunities and in some cases rates that are artificially higher than they should be. Rates reflect transmission charges that are often "pancaked" when electricity crosses several transmission networks, amassing layer upon layer of tariffs.[22] The overall goal of the new system is the creation of a national grid.

The Federal Energy Regulatory Commission (FERC) recently attempted to promote greater unification of the nation's electricity grid by consolidating the operations of several regional ISOs. The FERC's most recent effort at introducing more competition in the electricity industry was laid out in Order 2000, which was issued December 1999. Order 2000 advocates the formation of RTOs to operate the transmission network. Order 2000 requires that "each public utility that owns, operates, or controls facilities for the transmission of electric energy in interstate commerce" [***25***] be required to submit proposals on how they would participate in RTOs. Order 2000 stated no preference for RTOs to be publicly owned ISOs or privately held Transcos.[23] Order 2000 also took a stance in favor of "zonal pricing"[24] and extensively discussed performance-based ratemaking [***26***].

As a followup to its Order 2000 Rulemaking, on July 12, 2001, the FERC directed the formation of four RTOs in the Northeast, the Southeast, the West, and the Midwest. (Texas would be handled separately.) In the Northeast, it was expected that the PJM pool would merge with ISOs in New England and New York [***27***]. The FERC ordered the groups to use elements of the PJM as a platform for building the new organization. The FERC expects that RTOs representing the Northeast and Southeast will be the first in operation.

The intent behind the creation of RTOs is to improve the coordination of regional transmission activities, which should allow for greater flexibility and efficiency, fewer bottlenecks, and more electricity trade. One benefit of RTOs is that they may lessen the impact of pancaking. It is also hoped that RTOs will reduce discriminatory treatment directed at producers that do not own transmission lines.

Privatization

Naturally, privatization has been a feature of electricity reform only in those nations where electric utilities were publicly owned. Until recently, the United States, Belgium, Germany, and Japan were in general unique among countries in the degree to which privately held companies supplied electric power. For most other countries, electricity asset ownership was public.

Ideological and political factors have in part motivated the different paths undertaken to privatization. In some cases, where privatization was a major component of electricity reform, such as England and Wales, privatization of electricity preceded deregulation. In Australia, efforts to privatize and deregulate have proceeded piecemeal, and in New Zealand, Norway, and Sweden deregulation has occurred largely without privatization [***28***].

A less dramatic step than privatization involves the corporatization of electricity assets. New Zealand, for instance, during its initial electricity reform program

[21]Postage stamp rates refer to the situation where fixed transmission costs are recovered through a single access fee over an entire region.

[22]When multiple regions exist and a generator has to pay separate transmission access fees for moving power through each region, the rates are said to be "pancaked," because they are added on top of one another.

[23]Federal Energy Regulatory Commission, *Regional Transmission Organizations: Final Rule*, Docket No. RM99-2-000, Order 2000, 18 CFR Part 35 (December 20, 1999), p. 6, states: ". . . we do not propose to require or prohibit any one form of organization for RTOs or require or prohibit RTO ownership of transmission facilities. The characteristics and functions could be satisfied by different organization forms, such as ISOs, transcos, combinations of the two, or even new organizational forms not yet discussed in the industry or proposed to the Commission."

[24]Zonal pricing refers to the case where a region is broken into multiple subregions (zones) that have different wholesale electricity prices when transmission congestion occurs between the subregions.

transferred the nation's electricity assets from the Ministry of Energy to a newly created state-owned enterprise, the Electricity Corporation of NZ Ltd. Although the assets were to remain under government ownership, political control was diminished somewhat with the new accounting separation. Similarly, in New South Wales, Norway, Sweden, and Finland, where there has been a strong tradition of public ownership, privatization was not seen as an essential ingredient to achieving more competition in electricity supply. Rather, in general, the industries were reorganized to remove the monopoly franchise and to instill more commercial practices. Norwegian reform, for instance, separated the national grid from the power company.

Regulatory Reform

Several countries have attempted to deregulate the prices of various forms of energy service. Most of the deregulatory effort has focused on generation. For the wires business (transmission and distribution) the adoption of price-cap regulation and movement away from rate-of-return regulation has been a unique feature of recent regulatory reform efforts. The United Kingdom initiated what has become a much imitated model, allowing generation companies to sell their goods into a competitive market at competitive prices but applying a novel form of incentive regulation for the transmission and distribution sides of the business. Price-cap regulation attempts to restrain costs by applying price ceilings. Price-cap regulation was used as a means of instilling efficiency gains in the UK wire business. The price cap, known in the United Kingdom as RPI-X, allows for inflation-adjusted prices less expected efficiency gains. This form of "performance-based" regulation has been duplicated in other nations, including Argentina, Australia, New Zealand, and, in the United States, California and Texas.

Texas imposed a similar form of incentive regulation in its "price to beat." The "price to beat" is a price established to stimulate competition for sales to residential and small commercial customers. It is scheduled to go into effect in Texas in January 2002. For existing electric utilities the "price to beat" was set at 6 percent below the regulated retail rates in effect on January 1, 1999.

Open Access

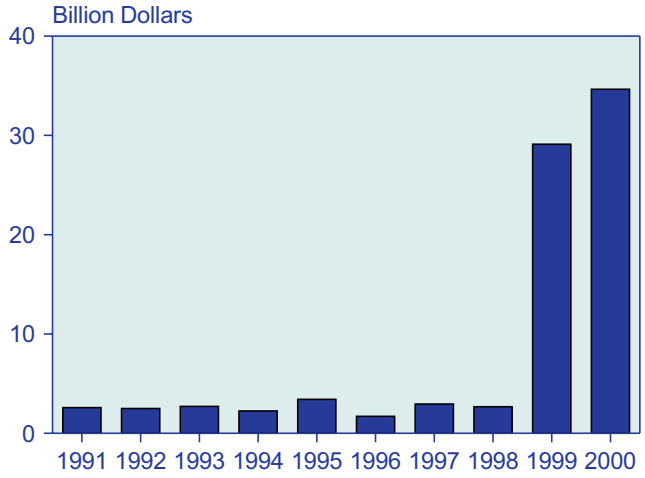
Nondiscriminatory open access to the electricity grid has been a major goal of electricity reform in Australasia, North America, Western Europe, and South America. New Zealand's transmission system has been open to all levels of demand since reform efforts got started in 1994. Norway introduced open access when it began its reforms in 1991. Western Europe is currently the scene of attempts to create a continent-wide electricity market. A 1996 European Community directive required all signatories to open up their electricity markets to new suppliers starting in February 1999.

Since opening their markets to non-incumbent suppliers, some countries have seen more or less switching among large customers. In some cases, switching has been deterred when incumbent suppliers have reduced prices in order to forestall market entry by new suppliers.

Foreign Investment

Although the desire to attract foreign investment has been an important motivation for electricity reform in the developing world, it has been the developed nations that have seen the greatest flows of foreign investment into their electricity sectors. For example, between the middle of 1995 and early 1997, U.S. utilities acquired 8 of the 12 privatized regional electricity companies in the United Kingdom, in transactions valued at more than $25 billion in total. Similarly, in Australia, many electricity assets were purchased by U.S.- and UK-based companies after Australia deregulated its electricity sector and opened it up to foreign investors. In turn, several companies from the United Kingdom have recently acquired U.S. electricity assets, a development heretofore rare in the U.S. electricity industry. The largest was Scottish Power's purchase of PacifiCorp of Oregon in 1999, valued at an estimated $12.9 billion. Indeed, the value of foreign investment in U.S. utilities rose from $2.8 billion in 1998 to $34.6 billion in 2000 (Figure 78),

Figure 78. Foreign Direct Investment in U.S. Utilities, 1991-2000



Note: The utility investments shown include, in addition to electricity, natural gas distribution and sanitary services; however, the sharp rise in investments during 1999 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* (various issues).

exceeding the value of U.S. investment in overseas utilities (Figure 79).

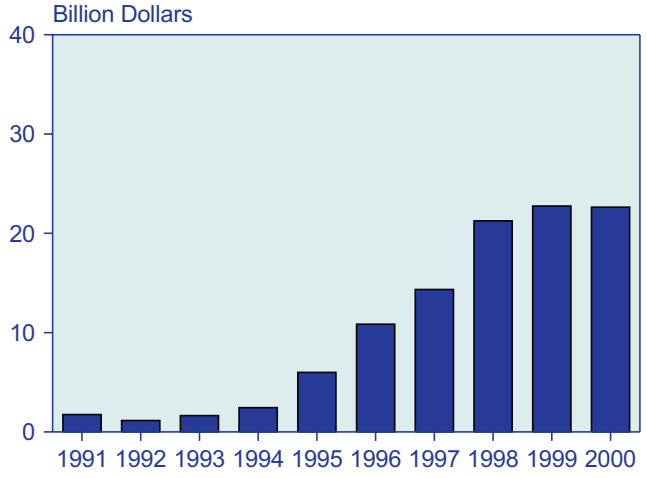
Developing nations have also attracted some foreign investment. In some instances, particularly in Asian nations, foreign capital has been restricted to greenfield electricity generation projects. In contrast, in South America, foreign investors have been allowed to acquire domestic utilities in their entirety.

Retail Competition

One of the most far-reaching of all electricity reform efforts has been to allow consumers to choose their electricity suppliers, which could in some ways be seen as the other side of open access. In general, retail choice has been offered first at the wholesale level to large, primarily industrial and commercial users of electricity. Offering the ability to choose one's supplier to households has not been as widespread, and in at least one instance (California) has been less successful than efforts to open up wholesale markets. One of the difficulties faced by new suppliers trying to encourage households to switch from their incumbent suppliers is that any savings that a new supplier might provide as a result of better management of its generation or wires business is likely to be only a small percentage of the average household electricity bill, which is heavily weighted toward such costs as service fees, hookup charges, and billing fees.

Some countries and states have, by and large, had good experiences with retail competition. Norway, New Zealand, Finland, Germany, Australia, the United Kingdom, and Pennsylvania have generally been successful in introducing competition at the household level. It has been suggested that by 2007 an estimated 500 million OECD consumers will be able to choose their electricity suppliers [***29***]. In the United States, roughly half of the States have adopted plans for retail competition, and retail competition is currently available in Massachusetts and Rhode Island. In Texas retail choice began in 2002 [***30***]. In Australia, the state of Victoria has offered retail choice since January 2001, and New South Wales is expected to offer retail choice by January 2002 and South Australia by January 2003.

Figure 79. U.S. Direct Investment in Overseas Utilities, 1991-2000



Note: The utility investments shown include, in addition to electricity, natural gas distribution and sanitary services; however, the sharp rise in investments from 1995 through 1999 is almost entirely 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* (various issues).

Retail choice has in some instances led to greater competition in electricity markets. Between October 1999 and February 2000, 7 percent of Scandinavian households switched electricity providers, and another 18 percent renegotiated electricity prices with incumbent suppliers [***31***]. By February 2000, 14 percent of consumers in England and Wales had switched suppliers [***32***]. In Germany, by the year 2005, "71 percent of industrial users, 45 percent of commercial users and 32 percent of residential users are expected to switch providers" [***33***].

California's experience with retail choice was less successful. In California, Assembly Bill 1890 provided customer choice by allowing more than 70 percent of California's electricity customers to change providers. By the time the retail market was opened to competition, 250 power marketing companies had signed up to sell electricity directly to California consumers. California consumers have, however, been reluctant to switch from their incumbent suppliers. They may have been discouraged by retail rate caps and by the fees charged for making a switch.

References

1. A.K. Izagure, "Private Participation in the Electricity Sector—Recent Trends," Public Policy for the Private Sector, Note No. 154 (Washington, DC: World Bank, September 1998).
2. International Finance Corporation, *Project Finance in Developing Countries* (Washington, DC: World Bank, May 1999).
3. International Finance Corporation, *Project Finance in Developing Countries* (Washington, DC: World Bank, May 1999).
4. K.G. Jechoutek and R. Lamech, "Private Power Financing—From Project Finance to Corporate Finance," Public Policy for the Private Sector, Note. No. 56 (Washington, DC: World Bank, October 1995).
5. J.E. Besant-Jones and B. Tenenbaum, "Lessons from California's Power Crisis," *Finance and Development*, Vol. 38, No. 3 (September 2001).

6. International Energy Agency, *Energy Prices & Taxes: Quarterly Statistics* (Paris, France, Third Quarter 2001).
7. Energy Information Administration, "U.S. Electric Utility Average Revenue per Kilowatthour (Retail Price) Data: Historical: Average Annual Revenue for All Sectors by State," web site www.eia.doe.gov.
8. Organization for Economic Cooperation and Development, *OECD Economic Outlook*, No. 67 (September 2001), p. 162.
9. International Energy Agency, *Competition in Electricity Markets* (Paris France, February 2001), p. 83.
10. A. Huber, D.T. O'Leary, and J. Charpentier, "New Paradigms for Information Processing in National and Regional Electricity Markets," Infrastructure, Business Briefing, World Market Research Center, web site www.wmrc.com/businessbriefing/pdf/infrastructure2001/tech/Siemens.pdf.
11. F. Woolf, "The Unbundling and Rebundling of Transmission and Market Related Functions," *Electricity Journal*, Vol. 9, No. 10 (December 1996), pp. 44-51.
12. National Economic Research Associates (NERA), *Transmission Pricing: International Developments* (Sydney, Australia, May 1998).
13. Energy Information Administration, *Electricity Reform Abroad and U.S. Investment*, DOE/EIA-0616 (Washington, DC, October 1997).
14. J. Chennells, "Electricity Trading the NETA Way," *World Power 2001*, pp. 166-167.
15. International Energy Agency, *Competition in Electricity Markets* (Paris France, February 2001), p. 83.
16. L. Carlsson, "The International Power Trade—The Nordic Power Pool," Public Policy for the Private Sector, Note No. 171 (Washington, DC: World Bank, January 1999).
17. P. Myrseth, "The Nordic Power Market and Its Use of Electronic Commerce," NORSK Regnesentral, web site www.nr.no/~pmyrseth/foredrag/oecd_ie_workshop_99/ (June 16, 1999).
18. Power Pool of Alberta, "General Information: History," web site www.powerpool.ab.ca.
19. D. Burtraw, K. Palmer, and M. Heintzelman, "Electricity Restructuring: Consequences and Opportunities for the Environment," Discussion Paper 00-39 (Washington, DC: Resources for the Future, September 2000), p. 66.
20. International Energy Agency, *Competition in Electricity Markets* (Paris France, February 2001), p. 89.
21. W.W. Hogan, "Regional Transmission Organizations: Millennium Order on Designing Market Institutions for Electronic Network Systems," web site www.ksg.harvard.edu/hepg/ (May 2000).
22. G. Shuttleworth, *Opening European Electricity and Gas Markets* (Washington, DC: National Economic Research Associates, November 2000), p. 16.
23. R.P. Lalor and H. Garcia, "Reshaping Power Markets—Lessons from Chile and Argentina," Public Policy for the Private Sector, Note No. 85 (Washington, DC: World Bank, June 1996).
24. International Energy Agency, *Competition in Electricity Markets* (Paris France, February 2001), p. 35.
25. Federal Energy Regulatory Commission, *Regional Transmission Organizations: Final Rule*, Docket No. RM99-2-000, Order 2000, 18 CFR Part 35 (December 20, 1999), p. 1.
26. Federal Energy Regulatory Commission, *Regional Transmission Organizations: Final Rule*, Docket No. RM99-2-000, Order 2000, 18 CFR Part 35 (December 20, 1999), pp. 157 and 397.
27. "FERC Maps New Vision of Grid—One with Four Major RTOs," *Electrical World*, Vol. 215 (July/August 2001), p. 6.
28. International Energy Agency, *Competition in Electricity Markets* (Paris France, February 2001), p. 33.
29. International Energy Agency, "Electricity Market Reform: California and Afterward," web site www.iea.org/about/emr.pdf (March 2001).
30. Energy Information Administration, *The Changing Structure of the Electric Power Industry 2000: An Update*, DOE/EIA-0562(2000) (Washington, DC, March 2000), p. 85.
31. "Retail Markets Over There: Has Supply Competition Taken Root?" Harvard Electricity Policy Group, Twenty-Second Plenary Session, Rapporteur's Summary, Session Two (Cambridge, MA, May 22-23, 2000), web site www.ksg.harvard.edu/hepg/.
32. L. Kiesling, *Getting Electricity Deregulation Right: How Other States and Nations have Avoided California's Mistakes*, Policy Study No. 281 (Los Angeles, CA: Reason Public Policy Institute, April 2001), p. 12.
33. L. Kiesling, *Getting Electricity Deregulation Right: How Other States and Nations have Avoided California's Mistakes*, Policy Study No. 281 (Los Angeles, CA: Reason Public Policy Institute, April 2001), p. 13.

Transportation Energy Use

Oil is expected to remain the primary fuel source for transportation throughout the world, and transportation fuels are projected to account for almost 57 percent of total world oil consumption by 2020.

Trends and Projections

Energy demand for transportation is projected to grow by 2.5 percent per year from 1999 to 2020, a higher pace than that forecast for energy demand as a whole (Table 24 and Figure 80). As a result, the transportation sector's share of total world energy consumption is projected to rise slightly, to just over 21 percent by 2020. Economic expansion and higher incomes are expected to increase the use of energy for transportation, as businesses and individuals demand greater mobility for themselves and their products. At the regional level, "transportation energy intensity"—defined here as the amount of energy used in the transportation sector per unit of gross domestic product (GDP)—is expected to decline in all regions over the forecast period (Figure 81), holding down some of the potential growth in transportation energy use. For the world as a whole, transportation energy demand per unit of GDP is expected to fall by 0.7 percent per year from 1999 to 2020.

The high oil prices and tight markets that characterized the world energy industry in 2000 were reversed in 2001. Even before the terrorist attacks of September 11, 2001, slowing economic growth and switching back to natural gas were moderating growth in oil demand [***1***]. The 2001 growth in energy demand for the transportation sector is likely to be the lowest in several years. From 1995 to 1999, energy consumption for transportation increased at an annual average rate of about 1 million barrels per day. In 2001, however, jet fuel and gasoline, the mainstays of the transport sector, both showed demand weakness that was exacerbated after September 11. World oil demand projections for 2001 were lowered to an increase of 0.4 million barrels per day in EIA's November *Short-Term Energy Outlook*, from 1.0 million barrels per day in the forecast before the attacks [***2***].

Jet fuel is expected to remain the fastest growing fuel for transportation, although the near-term outlook was severely weakened by the September 11 attacks. The demand for air travel fell significantly as a general reluctance to fly caused many travelers to postpone or cancel their travel plans. In the aftermath of the attacks, EIA estimated that jet fuel demand probably fell by about 10 percent outside the United States and as much as twice that within the United States. Jet fuel demand in the United States is estimated to have fallen by 11 percent in the second half of 2001 from year-earlier levels. A 1-percent increase is projected for the United States in 2002, and global jet fuel demand is expected to be down by roughly 5 percent [***3***].

Table 24. Transportation Energy Use by Region, 1990-2020

Region	Transportation Energy Consumption (Million Barrels Oil Equivalent per Day)				Average Annual Percent Change	
	1990	1999	2010	2020	1990-1999	1999-2020
Industrialized	**21**	**25**	**31**	**36**	**1.9**	**1.7**
North America	13	15	20	24	1.8	2.1
Western Europe	6	8	9	9	1.8	1.1
Industrialized Asia	2	3	3	3	3.0	1.1
EE/FSU	**4**	**2**	**3**	**4**	**-5.4**	**2.9**
Developing	**8**	**11**	**17**	**25**	**4.4**	**3.8**
Asia	3	6	10	16	6.4	4.9
Middle East	1	2	2	2	2.6	0.6
Africa	1	1	2	2	1.9	2.9
Central and South America	2	2	3	5	3.2	3.1
Total World	**33**	**39**	**52**	**65**	**2.0**	**2.5**

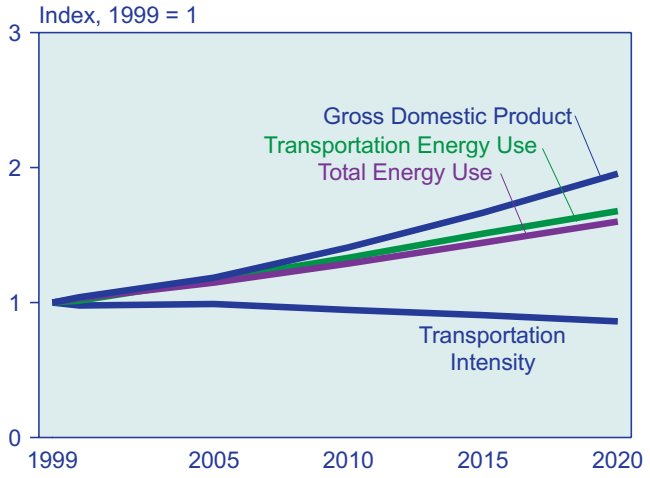
Note: Data include nonpetroleum sources of energy used in the transportation sector.

Sources: **History:** Derived from Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

The airline industry, which was showing signs of weakness before the attacks, has also been severely affected. In response to the drop in air travel, airlines in the United States have cut flights and announced job losses exceeding 100,000 [***4***]. The U.S. Congress allocated $15 billion to sustain the airlines as executives warned of imminent bankruptcies in the industry [***5***]. Airline troubles extended beyond the U.S. border due to the steep decline in international air travel and soaring insurance rates. Financial support was announced for several airlines, with some declared bankrupt and closed down or sold. French airplane manufacturer Airbus announced that it was freezing its production expansion plans at current levels, although it will still proceed with the development of its A380 super jumbo aircraft [***6***]. Airbus expects the number of the very large aircraft in service to reach 1,235 by 2019, more than half of which are expected to operate from only 10 airports [***7***].

Airport development continued in 2001, and growth in air travel is expected to remain robust in the long term; but finding space for new airports remains a problem. The new Inchon International Airport near Seoul, South Korea, is built on a man-made land bridge between two islands, following the example set by Japan's Osaka International Airport, which is built on a man-made island [***8***]. Japan is considering a new 1.6-mile runway for Tokyo's Haneda Airport, elevated 66 feet above sea level in Tokyo Bay in order not to interfere with maritime traffic [***9***]. Two locations are being considered for a new airport for Mexico City, one 22 miles from the city and the other 53 miles to the north [***10***].

Figure 80. Changes in World Gross Domestic Product, Energy Demand, Transportation Energy Use, and Transportation Intensity, 1999-2020



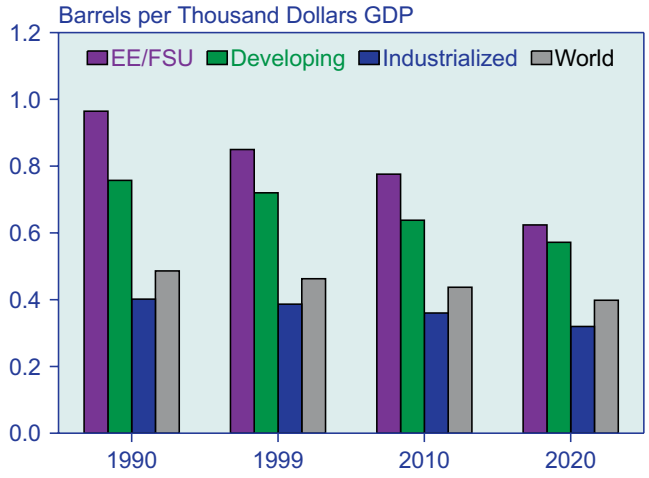
Sources: **1999:** Derived from Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **2000-2020:** EIA, World Energy Projection System (2002).

After jet fuel, diesel fuel is projected to show the strongest growth, further increasing demand for the middle of the barrel at the expense of gasoline and heavy fuel oil. Europe and South Korea currently have tax regimes that favor diesel over gasoline. Strong growth in diesel fuel is also projected for China and India. Some believe that the United States will have to move toward diesel if fuel efficiency standards are raised.

World vehicle ownership is projected to increase from 122 vehicles per thousand people in 1999 to 144 vehicles per thousand in 2020. Growth in per capita vehicle ownership is expected to slow in industrialized countries as saturation levels begin to be reached. In most of the developing nations, growth in vehicle ownership is expected to continue at a rapid pace. More rapid demand growth in the developing countries is a trend that is expected to occur throughout the transportation sector (Figure 82), and more than one-half of the increase in the world's transportation energy use is projected to take place in developing countries. With their higher economic growth rates and higher energy intensities, the developing countries' share of transportation energy demand is expected to rise from 29 percent in 1999 to 38 percent in 2020.

Future transportation demand trends will also be influenced by government policies directed at reducing emissions and congestion while promoting alternative fuels, new vehicle technologies, and mass transit. Such policies are aimed at vehicle efficiencies, the cost and quality of fuels consumed, the composition of fuels used for transportation, infrastructure development, and the research and development of new technologies.

Figure 81. World Transportation Energy Intensity by Region, 1990, 1999, 2010, and 2020



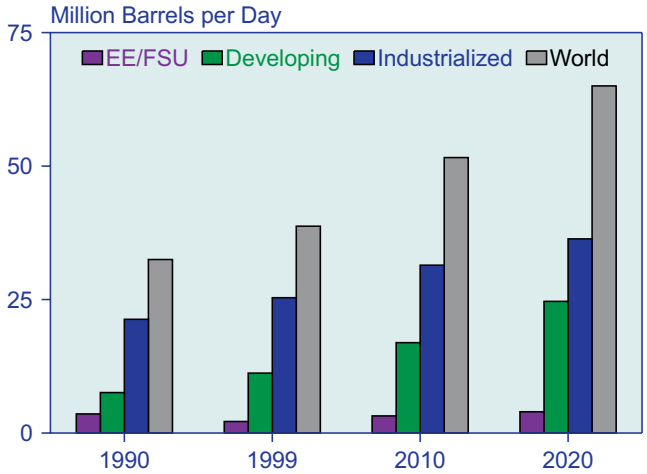
Sources: **1990 and 1999:** Derived from Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **2010 and 2020:** EIA, World Energy Projection System (2002).

Tensions among the goals of achieving economic growth, environmental improvement, and energy security are especially evident in the transportation sector. The ability to develop sustainable mobility and meet those three goals has been the focus of numerous studies and policy development activities. Over the past year, several governmental bodies around the world have produced or are in the process of developing transportation sector policies that could have considerable impact on the shape of future transportation trends, as discussed in the regional activity section below.

Sustainable mobility has become a catch phrase, defined as "the ability to meet the needs of society to move freely, gain access, communicate, trade, and establish relationships without sacrificing other essential human or ecological values today or in the future" [***11***]. It is being driven by the desire to improve urban air quality, reduce greenhouse gas emissions, and lower dependence on oil imports. Some have argued that it is through efficiency gains that sustainability is possible [***12***]. The focus is often on technological advances that will result in vehicles with few if any harmful emissions and significantly lower fossil fuel consumption. In the long term, sustainability is seen by many as a movement completely away from fossil fuels to a hydrogen-based energy system [***13***].

Alternatives to oil are being promoted to move toward sustainability goals in the near term. Compressed natural gas (CNG) and liquefied petroleum gases (LPG)[25] continue to be promoted in many countries. Thailand and Malaysia are experimenting with the development of fuel using palm and coconut oils, and Brazil, Mexico and Thailand are promoting ethanol from sugar cane. Although many countries are promoting alternatives to petroleum, their market share is expected to remain relatively small throughout the forecast, because market penetration is slow and the development of the infrastructure needed to support new energy sources remains daunting.

Figure 82. World Transportation Energy Use by Region, 1990, 1999, 2010, and 2020



Sources: **1990 and 1999:** Derived from Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **2010 and 2020:** EIA, World Energy Projection System (2002).

The share of transportation energy use made up by oil consumption is not expected to drop significantly in the *IEO2002* forecast, but oil's dominance may begin to be challenged by advancing technologies. Several technologies designed to improve the efficiency of internal combustion engines are already entering the market, including continuously variable transmission, which provides an infinite set of gear ratios, and displacement-on-demand, which turns cylinders on or off according to driving conditions. Gas-to-liquids (GTL) technology may be able to provide liquid fuels from a non-oil source without requiring major changes in fuel distribution infrastructure. Hybrid and fuel cell vehicles, however, are getting most of the attention as technologies that could significantly alter future transportation oil demand.

Most of the world's major automobile companies have plans to introduce some form of hybrid and / or fuel cell vehicle in the next decade. Honda and Toyota already have hybrid cars on the market. General Motors is developing a diesel hybrid bus, to be followed by hybrid pickups and sport utility vehicles, and expects to have gasoline-powered fuel cell vehicles developed by the end of the decade that will cut emissions to trace amounts and increase the fuel efficiency of today's vehicles by 50 percent [***14***]. DaimlerChrysler, Honda, and Toyota have also stated that they plan to have fuel cell vehicles developed by 2004 [***15***]. Honda Motor Company began road tests in July 2001 on a new fuel cell vehicle that runs on compressed hydrogen. The vehicle achieved driving performance closer to that of traditional vehicles, showing improvement over previous versions with regard to speed, acceleration, and cruising distance [***16***].

Significant technological, economic, and fueling infrastructure barriers remain for both hybrid and fuel cell vehicles. For example, the U.S. National Research Council has indicated that successful commercial application of fuel cells for passenger vehicles is at least 10 to 15 years away [***17***]. General Motors has also indicated that although fuel cell vehicles will begin to appear on streets in the next few years, they will be demonstration projects at least through the middle of the decade. Even if the projected cost reductions for fuel cell vehicles are

[25] Although LPG is an oil product, a large proportion is derived from wet natural gas streams. Because reserves of natural gas are widely dispersed, LPG use does not evoke the same security concerns as other petroleum products.

achieved, the economics still may favor traditional gasoline engines in countries where gasoline prices are relatively low [***18***].

One of the biggest obstacles to the penetration of fuel cell vehicles is the infrastructure needed to make the fuel widely available. For gasoline fuel cells the infrastructure is already in place, but infrastructure would have to be developed for methanol or hydrogen. In the United States a task force has been formed to draft a plan for the development of infrastructure for hydrogen-based vehicles and power plants. So far, it appears that the infrastructure needed to produce, transport, store, and distribute hydrogen will be very expensive to develop [***19***]. It may also be possible, however, to develop a dual-fuel engine that would run on gasoline as well, which would allow the infrastructure to be introduced gradually. BMW has unveiled a prototype car with a hydrogen-powered engine [***20***].

Although the existing distribution system favors gasoline fuel cell vehicles, hybrid vehicles may be able to achieve levels of fuel efficiency and emissions reductions comparable to those of gasoline fuel cell vehicles at a much lower cost. If so, it is possible that gasoline fuel cell cars could lose out to hybrids [***21***].

The movement toward advanced technologies will continue to put pressure on refiners to produce the cleaner fuels needed for fuel efficiency gains and emission reductions. Essentially sulfur-free gasoline and diesel, containing 10 parts per million (ppm) sulfur or less, will be needed for the most promising advanced engine and emission control systems. Even lower sulfur levels will be needed for fuel cell vehicles. In addition, gasoline with more tightly controlled distillation properties may be needed, as well as lower aromatics in both gasoline and diesel fuel [***22***]. Although refiners have resisted improving some fuel characteristics to the extent that automakers say they need, the movement toward cleaner fuels is a worldwide trend that is likely to continue.

Regional Activity

North America

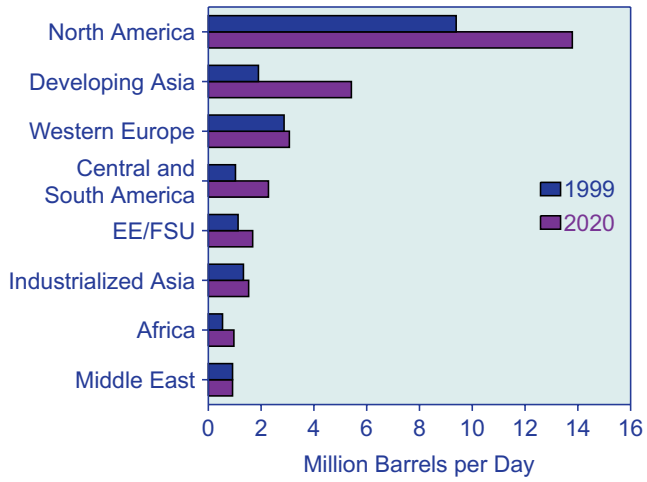
North America accounted for 39 percent of the world's fuel use for transportation and 49 percent of the world's gasoline consumption in 1999. The largest regional increase in gasoline demand in the forecast period is projected for North America (Figure 83), where gasoline currently captures 62 percent of the transportation fuels market.

United States

High prices and tight markets for energy fuels over the past several years have moved energy security and energy policy issues back into prominence in the United States. In May 2001, the Office of Transportation Technology (OTT) in the U.S. Department of Energy released a study on future highway energy use [***23***]. The study focused on advanced vehicle and fuel technologies as a means to lower oil consumption and reduce emissions without curtailing transportation service. Its purpose was to demonstrate that plausible alternatives exist, but that achieving them will require both continued technological advances and effective public policies. The study estimated that hybrid vehicles currently are 10 to 20 percent more expensive than conventional vehicles and that fuel cell vehicles are at least 20 percent more expensive.

The average fuel economy of new vehicles in the United States reached a 21-year low in model year 2001 at 20.4 miles per gallon, as a result of increased sales of sport utility vehicles, vans, and pickup trucks [***24***]. Higher vehicle fuel economy standards have been proposed as a means of reducing oil demand and imports [***25***], and a National Research Council study has suggested that automakers could significantly raise the fuel efficiency of passenger cars and light-duty trucks by 16 to 47 percent over the next 10 to 15 years [***26***]. Increasing corporate average fuel economy (CAFE) standards for light duty trucks, however, could result in a shift toward diesel fuel that would have implications for the refining industry. U.S. refiners normally target about a 2-to-1 ratio of gasoline to diesel production, and a significant decline could necessitate refinery modifications. In contrast to the United States, Europe typically exports gasoline and imports diesel fuel. If the United States shifts toward diesel fuel, the result may be excess gasoline production capacity and tight diesel markets [***27***]. In the absence of increased CAFE standards, EIA projects an increase of 0.3 percent per year in the fuel efficiency of the U.S. light-duty vehicle fleet [***28***].

Figure 83. World Motor Gasoline Demand by Region, 1999 and 2020



Sources: **1999:** Derived from Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **2020:** EIA, World Energy Projection System (2002).

The transportation sector is expected to contribute 89 percent of the projected increase in oil demand in the United States. One-fourth of the increase in world transportation energy use is expected to occur in the United States. Gasoline is expected to continue to dominate the sector, although its share is projected to decline slightly from 61 percent in 2000 to 58 percent in 2020.

Alternative fuels are not expected to penetrate the U.S. market to a large extent in the forecast period, despite some movement to alternative fuels. In California, 24 of the State's 43 largest transit agencies have opted for natural gas buses over diesel-powered engines with emissions reduction devices for ultra-low-sulfur diesel fuel. The natural gas buses are up to 15 percent more expensive but are far cleaner with respect to nitrogen oxide, air toxics, and soot [***29***]. CNG consumption in the United States is projected to grow by nearly 10 percent per year from 2000 to 2020.

Canada

Transportation energy use in Canada is projected to rise by 1.4 percent per year from 1999 to 2020. Canada has a transportation fuels market similar to that in the United States. Gasoline makes up 61 percent of Canada's transportation fuel demand, and its per capita consumption of transportation fuels is second only to that of the United States (12.4 and 17.8 barrels per person per year, respectively). Canada announced plans in February 2001 to harmonize certain fuel qualities with those of the United States in order to maintain product fungibility between the two countries. Sulfur levels in highway diesel fuel will be limited to 15 parts per million starting June 1, 2006, matching the U.S. requirement enacted in December 2000. Environment Canada is also developing future standards for off-road diesel and fuel oils and additional restrictions on gasoline [***30***].

Oil's share of transportation energy use in Canada is projected to remain at about 90 percent. The Government of Canada, however, is working with the alternative transportation fuels industry and major vehicle manufacturers to expand the use of fuel cells and fuels such as natural gas, ethanol, and electricity and is working to achieve new vehicle efficiency targets by 2010 [***31***]. In the 1990s, the average fuel efficiency of Canada's vehicle fleet improved despite the trend toward heavier and more powerful vehicles; however, with sales of minivans and sport utility vehicles expected to grow, efficiency gains are likely to be more challenging in the future [***32***].

The Canadian government launched a 12-month initiative in April 2001 to develop a federal strategy to respond to the major challenges that will face Canada's transportation sector over the next decade and beyond. The initiative will build on the work of the Canada Transportation Review Act Panel and the Transportation Climate Change Table. The Transportation Review Act Panel made a number of wide-ranging recommendations related to enhancing competition, evaluating mergers, financing infrastructure, developing policies, and other areas. The Transportation Climate Change Table provided options for reducing greenhouse gas emissions from transportation, the largest source of greenhouse gas emissions in Canada [***33***].

The Canadian Pacific Railway is calling for transportation policy that promotes competition and allows natural market forces to prevail, pointing out that Canada is the only country in the world that enjoys the benefit of two competing national railway systems that are not supported by taxpayers [***34***].

Mexico

Transportation energy demand in Mexico is projected to grow at the fastest rate among the industrialized countries. By 2020, per capita consumption of transportation fuels is expected to approach the level in Japan. Road use is expected to dominate, accounting for 82 percent of transportation consumption in 2020. The number of vehicles per thousand people in Mexico currently stands at 25 percent of the level in the United States but is expected to jump to 48 percent of the U.S. level by 2020, with gasoline comprising about 58 percent of the increase in transportation fuel use.

Mexico is studying the possibility of replacing the gasoline blending component methyl tertiary butyl ether (MTBE) with ethanol made from sugar cane. The Mexican sugar industry, unable to meet the challenge of fructose imports, is facing a severe crisis of overproduction. Producing ethanol would help to eliminate the surplus, in addition to doing away with the controversial ether [***35***]. MTBE has been detected in groundwater samples in the United States, causing several States to restrict its use.

Considerable progress has been made in reducing air pollution in Mexico City. Over the past 10 years, ambient lead concentrations have been reduced by 98 percent, sulfur dioxide concentrations have fallen to acceptable levels, and few violations of the carbon monoxide standard remain. Serious problems still persist, however, with high concentrations of ozone and particulates. The transportation sector is the main source of air pollution in the Mexico City metropolitan area. Several measures were enacted in the 1990s to improve air quality, including tax polices to reduce the price differential between leaded and unleaded gasoline, the installation of vapor recovery systems at service stations, the introduction of reformulated gasoline and low-sulfur diesel fuel, upgraded emission standards for new vehicles, and inspection and maintenance

programs. The creation of an Environmental Trust Fund through a surcharge on gasoline in Mexico City is considered to be an important step in sustaining the progress that has been made [***36***].

Western Europe

Sustainable mobility was the impetus behind a White Paper developed by the European Commission that proposed some 60 measures aimed at bringing about substantial improvements in the quality and efficiency of transport in Europe. It also presented a strategy designed to gradually break the link between constant transport growth and economic growth, in order to reduce the pressure on the environment and prevent congestion while maintaining competitiveness. The proposals included a harmonization of fuel taxes across the countries, infrastructure development concentrating on filling in the missing links in trans-European networks, and improving safety and quality. Other measures were aimed at developing fair infrastructure charging, taking into account external costs and encouraging the use of the least polluting modes of transport. Another proposed objective was to shift the balance between modes of transport by 2010 by revitalizing the railways, promoting maritime and inland waterway transport, and linking up the different modes of transport [***37***]. Since 1980, the length of the European Union (EU) motorway network has increased by more than 70 percent, but railway lines and inland waterways have decreased by about 9 percent. Sixty percent of the international funding for the trans-European transport network has been targeted for rail, but actual investments are still biased toward highways [***38***].

Gasoline consumption in Western Europe in 1999 was at the same level as in 1990. Despite growth in car traffic, the static gasoline market resulted from the use of smaller, more efficient cars and the shift to diesel fuel. Consumers have been encouraged to purchase diesel-fueled cars through beneficial taxation policies, the development of efficient engines, and the perception that the fuel is more environmentally friendly [***39***]. These trends are projected to continue, with diesel fuel consumption estimated to rise by 0.7 million barrels per day from 1999 to 2020 (Figure 84) and gasoline by 0.2 million barrels per day.

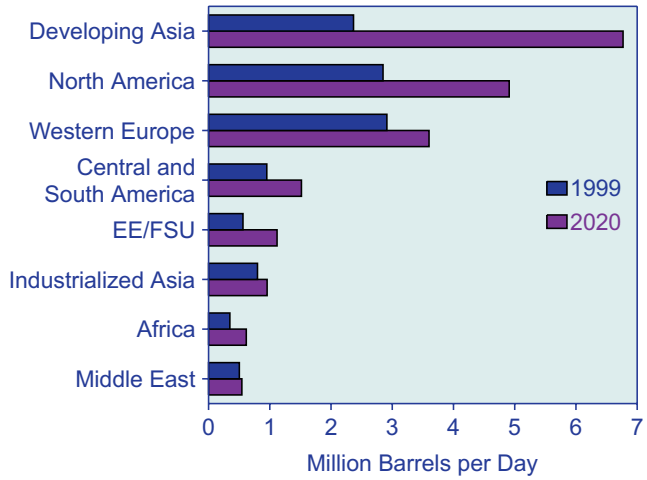
The European Commission has also indicated that it plans to introduce a harmonized excise duty on diesel fuel across the EU that would be higher than the current average tax on diesel. The medium-range goal would be to tax gasoline and diesel similarly for all users. Exemptions for hydrogen and biofuels are expected to be included, not only for environmental benefits but also as a way to boost energy security [***40***].

The September 11 attacks in the United States severely affected airline companies in Europe. British Airways cut 7,000 jobs and reduced operations by 10 percent [***41***]. Swissair, which had been having financial difficulties for months, suspended operations on October 2 and resumed flights only after the Swiss government stepped in with a bailout package [***42***]. The European Commission approved compensation for losses that stemmed from the cancellation of flights to and from the United States for four days after September 11 but made it clear that no public subsidy would be permitted for any other reason [***43***]. Restructuring in the European airline industry is expected to result in only four or five international carriers plus an ensemble of regional carriers [***44***]. In the long term, however, strong growth in jet fuel consumption is expected. The increase in jet fuel consumption from 1999 to 2020 is projected to equal that of gasoline and diesel fuel for transport combined. By 2020, demand for air travel is expected to reach 19 percent of the region's transportation energy demand.

The United Kingdom is projected to contribute 22 percent of the increase in transportation energy use in Western Europe from 1999 to 2020. Consumption for air travel makes up a larger proportion of transportation demand in the United Kingdom than in continental European countries, and that share is projected to reach 27 percent by 2020. Despite the growth in air travel, London and the Southeast United Kingdom have added little runway capacity in the past 50 years. The Confederation of Business Industry has called for expansion of airport capacity, stating that it is essential for business and economic growth [***45***].

Despite the lower proportion of fuel consumption for road use in the United Kingdom as a whole, the people of London listed traffic congestion as the number one

Figure 84. Diesel Fuel Demand by Region, 1999 and 2020



Sources: **1999:** Derived from Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **2020:** EIA, World Energy Projection System (2002).

transportation issue that they wanted tackled. In addition to proposals to expand the capacity of the rail and subway lines, the Mayor of London has proposed congestion charging as a means to reduce traffic in the city [***46***].

Higher prices and a weak euro resulted in a small decrease in oil consumption in France in 2000. Diesel consumption, however, continues to increase due to a favorable tax regime. In 2000, 34.7 percent of privately owned cars in France had diesel motors, and a record 49 percent of new registrations were for diesel cars [***47***]. While the share of gasoline declines, diesel fuel is projected to continue to make up more than one-half of total transportation energy use in France.

Germany is the largest transportation market in Western Europe. Ultra-low-sulfur gasoline and diesel fuels (50 ppm) were introduced on November 1, 2001, without the price spikes and market disruptions sometimes associated with changes in product specifications. The fuels were brought into the market using tax incentives rather than mandates. Domestic refiners are producing most of the low-sulfur gasoline, but a significant portion is being imported [***48***]. Gasoline made up 50 percent of Germany's transportation fuel market in 1990, but its share is expected to fall to 43 percent by 2020. Strong growth is projected for jet fuel and diesel fuel consumption.

In an effort to improve air quality, Germany slashed the excise duty on CNG to a quarter of that on gasoline and diesel until 2009. That brings CNG down to 60 percent of the cost of traditional fuel on an energy equivalent basis. Excluding taxes, CNG is still 8 percent more expensive than natural gas delivered to households, which provides incentives to suppliers. Natural gas pumps are expected at 1,000 filling stations within 5 years. The program is aimed chiefly at commuters. CNG vehicles have a range of 109 to 124 miles, and the tank takes up about half a normal car's trunk space. The goal is to have 1 million vehicles running on natural gas by 2006, up from about 10,000 currently [***49***].

Italy ranks second to Argentina in numbers of natural gas vehicles with about 370,000 or about 1 percent of all vehicles. Italian motorists have been encouraged to switch from gasoline to CNG since the 1930s, when the wartime government was anxious to lessen reliance on imported oil [***50***]. At 612 vehicles per thousand people, Italy's per capita vehicle ownership is higher than that of Germany, France, or the United Kingdom. Road use fuel consumption currently amounts to 84 percent of Italy's transportation energy demand, ranking among the highest in Europe, and it is expected to remain relatively high at 80 percent in 2020.

Austria's OMV oil and gas group plans to install 20 new natural gas filling stations over the next 3 years, given a pending reduction of excise duty on CNG. An Austrian network would enable motorists using CNG to drive from the northern part of Germany to southern Italy. The company estimates that 1 to 2 percent of Austria's vehicles could be running on CNG within 10 years [***51***].

Industrialized Asia

Transportation energy demand in industrialized Asia is projected to increase by 1.1 percent per year from 1999 to 2020, down from its 3.0-percent average annual growth rate from 1990 to 1999. Slower economic growth is expected for the region, and per capita vehicle ownership levels are already high, contributing to the expectation of slower growth in transportation fuel use.

Australia

The need to overcome large distances contributed to development of the transportation sector in Australia. About 567,302 miles of highways, 21,014 miles of rail, and more than 400 airports provide transportation infrastructure for the movement of goods and people [***52***]. Jet fuel's share of total transportation energy use is one of the highest among the countries in the forecast, and Australia has the second highest national per capita vehicle ownership rate after the United States.

Australia is expanding the number of CNG refueling sites, with the total expected to exceed 30 stations in the next 18 months. It is hoped that the increase in refueling sites will encourage motorists to consider the economic and environmental benefits of converting to CNG. With CNG sourced entirely within the country, prices are not affected by fluctuations in world crude oil prices or exchange rates [***53***].

Ansett Airlines became one of the victims of the post-September 11 slowdown in air travel. It ceased operations in September until the Australian government decided to underwrite tickets to get five airplanes back in operation. Quantas Airways picked up much of Ansett's 39-percent share of the Australian domestic air travel market, which helped to shield Quantas from the slowdown in international demand [***54***].

Japan

Despite the economic malaise of the past decade, per capita vehicle ownership in Japan grew at a higher rate than any other industrialized country in the forecast except Mexico. It was the used car market, however, that had the biggest boom. In contrast to 1990, when new car registrations were about 20 percent higher than used cars, used car registrations now exceed those for new cars by about 37 percent. Toyota and Honda are accelerating efforts to expand their used-car businesses in hopes of promoting sales of their new cars [***55***].

The market for mini-vehicles with lower costs and higher efficiencies is also growing in Japan. (Mini-vehicles are defined as vehicles with 0.66-liter engines or

smaller.) New mini-vehicle sales rose by 21.2 percent to a record 1.88 million units in 1999, the first gain in 4 years [***56***]. The use of smaller, more efficient vehicles and greater reliance on mass transit has helped to give Japan the lowest level of transportation energy consumption per unit of GDP among the countries in the forecast. In 1999, Japan's transportation energy intensity was 57 percent of the level in Western Europe and 31 percent of the level in the United States.

Public works projects have become a source of contention as the Japanese government steers between getting its runaway budget deficit under control and providing fiscal stimulus to keep the economy from sliding further into recession [***57***]. This was evident when three research councils associated with the ruling Liberal Democratic Party jointly adopted a resolution calling for full implementation of an expressway construction program, resisting Prime Minister Koizumi's plans to scale back Japan's expressway projects [***58***].

The Japanese Ministry of Land, Infrastructure and Transport is proposing to expand Tokyo's Haneda Airport rather than build a third airport in the greater Tokyo area [***59***]. Haneda's international flights had been limited to only those of Taiwan's China Airlines until February 2001, when Japan's three major airlines and two South Korean airlines were allowed to begin some international charter flights [***60***]. Tokyo's Narita Airport wanted to add a 1.6-mile runway to accommodate larger passenger airlines but was forced to scale back plans to only 1.4 miles as a result of disputes with farmers living next to the airport [***61***]. Until May 2001, Narita had only one runway, 2.5 miles in length [***62***].

Developing Asia

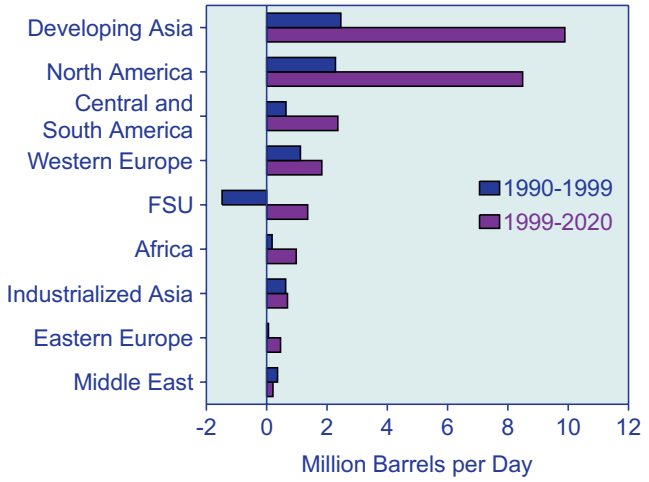
Developing Asia is expected to have the highest growth rate among the regions in the forecast, and transportation energy demand in the region is projected to exceed that in Western Europe by 2010, making it second in transportation fuel consumption after North America. Developing Asia is projected to account for 38 percent of the increase in world transportation energy demand from 1999 to 2020 (Figure 85), with an annual average growth rate of 4.9 percent. Jet fuel demand is expected to increase more than fourfold (Figure 86), and gasoline and diesel fuel consumption are projected to nearly triple.

China

The transportation sector was left out of China's economic plans for many years, and the resulting lack of infrastructure is a major bottleneck for the country's energy sector and overall economy. China has recently begun working on the development of roads, railways, and inland waterways. In 1999, the total length of operational freeways reached 7,208 miles, ranking third in the world behind the United States and Canada. China also plans to develop a high-speed railway network around the country.

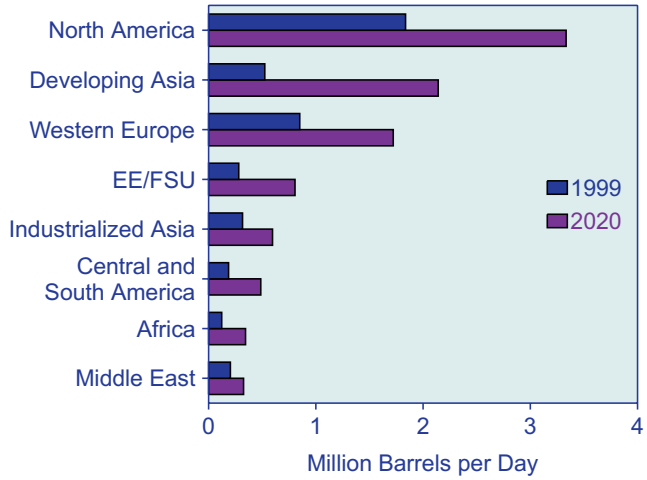
China's vehicle stock is dominated by heavy commercial vehicles, but passenger cars are expected to be the fastest growing component of in the forecast. Mass transit is expected to continue to dominate, however, and car density is expected to remain low in comparison with industrialized countries [***63***]. The number of vehicles per thousand people in China is projected to reach 52 in 2020

Figure 85. Changes in Transportation Energy Use by Region, 1980-1999 and 1999-2020



Sources: **1980-1999:** Derived from Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **1990-2020:** EIA, World Energy Projection System (2002).

Figure 86. Jet Fuel Demand by Region, 1999 and 2020



Sources: **1999:** Derived from Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **2020:** EIA, World Energy Projection System (2002).

from 12 in 1999. The projected strong growth in automobile sales reflect China's economic growth, the development of car financing, efforts to make car ownership easier, the launch of new models, and greater price competition [***64***].

Transportation energy demand in China is projected to grow by 6.4 percent per year from 1999 to 2020, increasing its share of world energy use for transportation from 4.1 percent in 1999 to 9.1 percent in 2020. China is expected to pass Japan by 2005 and become the world's second largest consumer of transportation fuels. The strongest growth is projected for gasoline, and gasoline consumption in China is expected to exceed that in Western Europe by 2020.

In 2000, China began to tie domestic petroleum product prices to international prices in Singapore. The prices were linked to the previous month's averages on Singapore's spot market, enabling wholesalers to estimate the price trends in advance and determine product volumes accordingly. This resulted in large demand swings for refiners and left them with unsold product. As a result, starting in October 2001, domestic gasoline and distillate prices were linked to Rotterdam and New York prices as well as Singapore. Linking the prices to Rotterdam and New York in addition to Singapore is expected to even out price volatility and limit the scope for manipulation [***65***].

The Air Transport Action Group predicts that China will overtake Japan as the dominant market for air travel in the Asia-Pacific region, projecting a rise from 70 million passengers annually in 1999 to 200 million by 2014 [***66***]. Pudong International Airport in Shanghai is planning to build a second runway and undergo further expansion that will make it the busiest airport in China and one of the busiest airports in the world by 2010 [***67***].

India

India's consumption of energy for transportation is projected to rise by 6.8 percent per year from 1999 to 2020. making it the third largest after the United States and China. On a per capita basis, however, India still would rank among the lowest in the world.

India has been advancing the use of CNG in an effort to reduce air pollution. Gujarat Gas Company, Ltd., is developing a compressed natural gas business in Gujarat. It has a pipeline network that feeds gas to users in the Surat, Ankleswar, and Bharuch areas and is already supplying CNG to about 800 vehicles in Surat city [***68***].

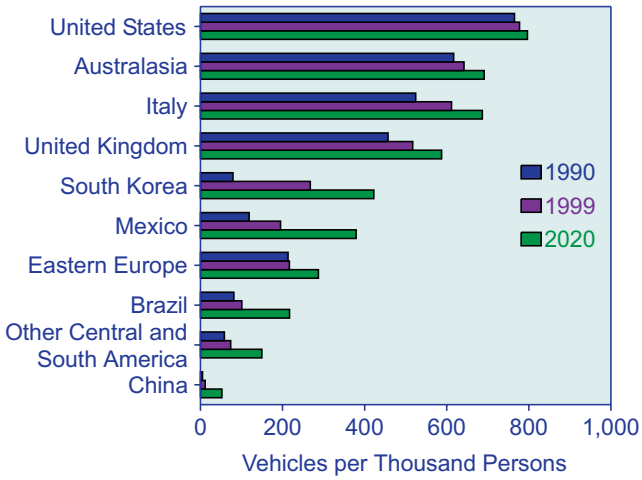
Delhi's compulsory transition of the city's entire public transport fleet to CNG revealed some of the difficulties that alternative fuels face. In July 1998, India's Supreme Court set a deadline of March 31, 2001, for the public transport fleet in Delhi to be converted to CNG. A month before the deadline, however, only a fraction of the fleet had been converted, and the city had only three CNG bus filling stations [***69***]. The court extended the deadline to September 30, 2001, but restricted the number of diesel buses to the number of orders placed for new CNG buses or for conversions [***70***]. By October, only about one-third of the bus fleet was using CNG, and the court agreed to allow extra time. A new deadline is expected after the court reviews detailed plans and timetables from authorities and receives input from bus manufacturers, conversion agencies, and the gas supplier, Indraprastha Gas, Ltd. [***71***].

The Tata Energy Research Institute (TERI) called for the consideration of ultra-low-sulfur diesel as an alternative to CNG buses in Delhi, arguing that similar air pollution benefits could be obtained for a much cheaper price. TERI also pointed out some of the problems in the decisionmaking process, that the economics of the changeover and the practical feasibility of putting the infrastructure in place were not carefully considered, and that the decision was made without any trials being carried out under operating conditions [***72***]. The transition is being made, but the process has proven painful for those involved.

South Korea

Per capita vehicle ownership in South Korea increased by 14.5 percent per year from 1990 to 1999. The pace is expected to slow in the forecast period, but by 2020 the number of vehicles per thousand people in South Korea is projected to equal 53 percent of the level in the United States, as compared with 10 percent in 1990 (Figure 87). South Korea's automobile manufacturers have been

Figure 87. Motorization Levels in Selected Countries, 1990, 1999, and 2020



Sources: **1990 and 1999:** Derived from Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **2020:** EIA, World Energy Projection System (2002).

struggling since the financial crisis of 1998. General Motors Corporation acquired Daewoo Motor Company in September 2001. Daewoo had been in court receivership since filing for bankruptcy in November 2000 after negotiations with Ford Motor Company broke down [***73***]. Hyundai/Kia is now the lone Korean-owned manufacturer [***74***].

Gasoline consumption makes up just 26 percent of the transportation fuel market in South Korea, primarily because its gasoline prices are among the highest in the world. Diesel fuel is less than half as expensive, and its consumption for transportation is 34 percent higher than that of gasoline [***75***]. Consumption of LPG for transportation use increased by nearly 25 percent per year in 1999 and 2000 and by another 13 percent in the first 3 months of 2001 [***76***]. That rapid growth is likely to slow, however, after a fourfold increase in the excise tax on LPG that started July 1, 2001. Additional tax increases are planned every 6 months for the next 5 years to bring the LPG price from 22 percent of the cost of gasoline to 65 percent. The government also plans to raise the excise tax on diesel fuel to bring its price to 80 percent of the gasoline price [***77***].

Jet fuel demand in South Korea is projected to more than triple over the forecast period. A new airport has been built in the greater Seoul area, Inchon International Airport, which can handle as many as 27 million passengers and 1.7 million tons of freight each year. South Korea is hoping that the new facility will help it compete with rival facilities in northeast Asia [***78***].

Other Developing Asia

The Thai cabinet approved a scheme that included builder tax incentives for four new ethanol plants using sugar cane and other crops. The government plans eventually to use ethanol in a 10-percent blend in all gasoline in an effort to reduce imports of oil and MTBE [***79***]. In July 2001, the government exempted non-petroleum portions of fuel from taxes, providing additional incentives for blending with ethanol and other alternative fuels. Higher oil prices and lower coconut and palm oil prices have led to renewed interest in biodiesel production. King Bhumibol Adulyadej holds a patent on palm-oil biodiesel, and a coconut-oil biodiesel process was patented in March 2001. The Petroleum Authority of Thailand (PTT) has been selling 3,000 to 4,000 liters (793 to 1,057 gallons) daily of 5 percent refined palm-oil biodiesel since July when the tax exemption began [***80***].

In spite of a growing vehicle population, Bangkok's air has become quantifiably cleaner over the past few years. Leaded gasoline has been banned since 1996, and all cars exported to and produced in Thailand are required to meet European emission standards. In 2001, 90 percent of new motorcycles sold in Bangkok were cleaner, more fuel-efficient four-stroke models. In addition, open green space in Bangkok has more than doubled since 1993. While more progress is needed, Bangkok is slowly making improvements in air quality [***81***].

Jakarta, Indonesia, ranks as one of the most polluted cities in the world due in large part to automobile emissions. In 2000, atmospheric lead pollution was measured at 1.3 micrograms per cubic meter, above the World Health Organization limit of 0.5 to 1.0 micrograms per cubic meter. Controlling air pollution has been difficult because the economic slowdown has not hindered the growth in the number of vehicles, which has continued at 15 percent per year, but has made it more difficult for Pertamina, the national oil company, to secure loans to build catalytic reformers to provide the high-octane blending components needed to produce unleaded gasoline [***82***]. Indonesia is still planning to phase out leaded gasoline by 2003. Pertamina is continuing to upgrade its refineries to meet the fuel standards but expects that imports of unleaded gasoline may be needed to meet demand [***83***].

Air quality has deteriorated significantly in Hong Kong in recent years. Vehicles are the primary cause of street-level pollution, producing smoke, particulates, and chemicals in quantities that regularly exceed health standards. In May 2001, participants in a Cleaner Vehicles and Fuels Workshop gathered ideas and developed action plans for reducing vehicle emissions. The group recommended that Hong Kong establish an Energy Commission to develop a clear, coordinated energy policy. The Commission would develop long-term policies to remove barriers to the introduction of cleaner vehicles and fuels, adopt performance-based incentives to promote the cleanest vehicles and fuels infrastructure, develop an integrated education and training strategy, and promote research and development. The ultimate goal is to achieve zero emissions from transportation, probably by means of hydrogen-powered fuel cell vehicles [***84***].

Central and South America

Central and South America is one of the most urbanized regions of the developing world, with approximately 80 percent of its population residing in metropolitan areas and more than 55 metropolitan areas of 1 million inhabitants or more. The process of urbanization has occurred fairly rapidly and has accelerated dramatically in the past 30 years. The urban transportation sector is commonly regarded as one of the main culprits behind the high levels of urban air pollution in the region [***85***].

Congestion is also a major problem. Per capita vehicle ownership in Central and South America is much higher than in other developing regions, although it remains considerably lower than in the industrialized countries.

The number of vehicles per thousand people in Central and South America is projected to increase to 215 by 2020. Some cities have begun a strategy of deemphasizing cars and providing public transport instead. Curitiba, Brazil, built a system of dedicated busways and zoned for higher density development along those thoroughfares. The city now enjoys better air quality and more parks for its 2.5 million people. Car-free days are also being used to promote public transportation and reduce dependence on cars [**86**].

Most of the countries in Central and South America have phased lead out of gasoline in the past several years. When Venezuela completes its lead phasedown program, nearly all gasoline in the region will be lead free. Venezuela has targeted 2015 for lead phaseout, but discussions are under way to move up the date. Venezuela will likely accomplish the phaseout by converting its large leaded premium pool into unleaded regular gasoline with minimal octane loss [**87**].

Brazil

Brazil has nearly 1.2 million miles of roads—more than twice as many as Australia, Canada, or Russia—but less than 10 percent are paved [**88**] and road conditions in the rural sections are often poor [**89**]. The road portion of transportation energy use in Brazil is projected to decline slightly to 84 percent by 2020, and per capita vehicle ownership is expected to more than double to 217 vehicles per thousand people.

Congestion and air pollution are big problems in Brazil's cities. In 1999, 90 percent of Sao Paulo's smog resulted from motor vehicle emissions. Sao Paulo's pollution levels are fueled by poor infrastructure design, gasoline prices that are among the lowest in the world, and inefficient automobiles. The local government instituted a pollution control program in 1999 requiring that motorists leave their cars home one day a week. An orbital motorway, additional metro lines, and improvements to the rail system are also planned to improve environmental conditions [**90**].

Gasoline in Brazil consists of about 20 percent ethanol made from sugar cane. The Brazilian National Alcohol Program started in the 1970s as an alternative to oil and to promote self-sufficiency. The ethanol market is regulated to keep the price competitive with gasoline [**91**]. Gasoline prices are controlled at the refinery but not at the pump. Refinery prices are adjusted every 3 months, taking into account international oil prices and the value of the Brazilian real in relation to the U.S. dollar [**92**]. The Petrobras monopoly on refining and distribution of petroleum products came to an end in 1998, and since then other companies have sought to expand into Brazil's market. Petroleos de Venezuela (PDV) has plans to open a number of gasoline stations in Northeastern Brazil starting in the fourth quarter of 2001 [**93**].

Argentina

Argentina's recession continued, with the economic situation deteriorating sharply in the summer of 2001. The International Monetary Fund (IMF) provided additional monetary assistance in September 2001, but most analysts do not think it will be sufficient to prevent further financial difficulties [**94**].

Argentina has an extensive transportation network, much of which has been privatized over the past decade. Maintaining and upgrading the highway system is a challenge in a country that stretches 2,485 miles from north to south. Argentina has 133,592 miles of highways, of which 29 percent are paved [**95**]. An estimated 87 percent of passenger and 85 percent of domestic freight traffic is carried by road. The most highly traveled sections of more than 30 national highways have become privately operated toll roads. Traffic managers have stressed that improved road conditions on those highways reduce vehicle maintenance costs and travel time, more than making up for the fees that drivers have to pay. Moreover, the government has been able to apply road taxes to repair secondary roads, pave dirt roads, and construct new roads [**96**].

Some 8 million cars and a large fleet of buses operate in the city of Buenos Aires each day, creating serious health problems [**97**]. A workshop sponsored by the World Bank Clean Air Initiative identified improved inspection and maintenance systems and the planning and development of a cycle lane system as two important projects to help reduce emissions and congestion [**98**]. In addition, Argentina is planning to reduce sulfur levels in gasoline and diesel fuel to 50 ppm by 2006 [**99**]. Tax incentives for biodiesel have been announced in an effort to help farmers as well as reduce emissions. The incentives, which extend to excise, income, and property taxes, could allow production of biodiesel at sales prices well below that of regular diesel fuel [**100**]. Argentina also has 687,000 natural gas vehicles, more than any other country in the world [**101**].

In the early 1970s, Argentina could boast that all its cities with a population of 10,000 or more (with the exception of Ushuaia in Tierra del Fuego) were served by rail; however, government ownership led to management decisions that were often based on politics, government priorities, and expediency. Investment and research and development were deemphasized, and by the late 1980s huge operating subsidies were required to keep the system running at even a marginal level. Since 1992, all but one of Argentina's railways have been privatized. Since privatization, the passenger and freight traffic have

risen and service has improved. The railroad industry is also trying to improve its relationship with ports to persuade traders that rails can serve them as well as trucks [**102**].

Waterways are an important part of Argentina's transportation sector. Nearly 90 percent of the country's foreign trade passes by water through its sea and river ports. Argentina has 2,175 miles of navigable waterways. Since privatization, investment has gone into increasing port capacity and improving operations. The work force has been reduced by 75 percent, management has been restructured, and operations have been streamlined. Argentina's move to revamp its marine terminals and waterways should bolster the country's increasingly important waterborne trade [**103**].

Aerolineas Argentinas was grounded for 5 months in 2001 after declaring bankruptcy protection when two of the seven unions representing its employees refused to go along with a restructuring plan that would have slashed wages and benefits in return for guaranteed job continuity. Flights resumed in November under new ownership [**104**].

Middle East

Gasoline makes up a larger share of the transportation fuel market in the Middle East than in other developing regions. As a result of slower growth in motorization rates, transportation demand in the region is projected to increase by 0.6 percent per year from 1999 to 2020. Jet fuel is expected to show the strongest growth as air travel expands in the region.

The large increase in traffic that has ensued from Saudi Arabia's economic development made it necessary to upgrade several of the nation's inter-city roads to multi-lane expressways. Traffic congestion in the cities has also resulted in the development of ring roads around city centers, as well as overpasses and underpasses to keep traffic flowing [**105**]. Air pollution in Saudi cities is the lowest in the Middle East and should continue to improve with the introduction of unleaded gasoline in January 2001. The switch to unleaded gasoline will result in the need for an estimated 3 million catalytic converters in order to reduce pollution from vehicle exhaust [**106**].

In 1945, U.S. President Roosevelt presented Saudi King Abdul Aziz with a DC-3 Dakota airplane. The King quickly realized the contribution that air travel could make to the development of the Kingdom and promptly ordered two more planes. Saudi Arabia now has three international airports and 22 regional and local airports, linking together all parts of the country [**107**].

Dubai International Airport in the United Arab Emirates is the fastest growing airport in the region. It handled 6.8 million passengers in the first half of 2001, up by 14 percent from the same period in the previous year. Freight traffic increased by 8 percent [**108**]. A $2.5 billion expansion program was announced to add another terminal and two concourses. Completion is planned for 2006 [**109**].

Africa

Maintaining the road infrastructure has been a big challenge for much of Africa. At the end of the 1980s, Sub-Saharan Africa had nearly 1.2 million miles of roads worth about $170 billion, but nearly one-third of that investment has been lost through lack of maintenance. A Road Maintenance Initiative (RMI) was launched, bringing the roads into the marketplace, setting fees for use, and managing them like any business enterprise. Although the pace and impact of reform have been slower than expected, several countries have shown substantial increases in the proportion of main roads designated as "good." Conditions on rural and feeder roads have not improved, however, and the Sub-Saharan Africa Transport Policy Program is accessing obstacles to continued improvements and ways to overcome them [**110**].

Former Soviet Union

Transportation energy demand declined by 7.3 percent per year from 1990 to 1999 in the former Soviet Union (FSU) as a result of the turmoil that accompanied the end of the Soviet era. Trucks used to dominate the traffic on Russian city streets, but private car ownership grew rapidly in the 1990s [**111**]. Road use energy demand in the FSU is projected to increase by 3.3 percent per year from 1999 to 2020 and jet fuel demand by 4.8 percent per year. By 2020, transportation energy demand in the FSU is expected to be at nearly the same level as in 1990.

Infrastructure development remains a serious concern in Russia. In the 1990s, roads, bridges, and other infrastructure fell into an advanced state of decay, and investment was inadequate for the needed repairs [**112**]. As fast as the Russian economy declined, investment declined even faster. A combination of low domestic savings, limited foreign investment, and government deficits resulted in an investment crisis that hindered infrastructure development [**113**]. Over the past several years, however, Russia has shown strong economic growth. Higher oil prices, exchange rate depreciation, and moderating inflation have contributed to a renewal of economic growth and an improved investment climate [**114**].

Eastern Europe

Transportation energy demand in Eastern Europe fell as a result of the economic turmoil that occurred after the collapse of the Soviet Union, but from 1990 to 1999 it grew at an average annual rate of 1.1 percent. The

transportation infrastructure in Eastern Europe shows the effects of 40 years of central planning and lack of investment. The density of the national public road networks and their quality are generally lagging far behind road network standards of EU countries. Many roads are in poor repair because they were not made to handle the current high volumes of traffic and the weight of modern trucks [***115***]. Travelers and goods used to move mainly by train but the importance of railways is decreasing and the future of many rural lines is uncertain. The frequency of service has declined and fares have increased [***116***]. Fuel quality also lags behind that in Western Europe, but countries in Eastern Europe are working hard to improve fuel quality to harmonize with EU fuel standards. Gasoline's share of the market is much higher in Eastern Europe than in Western Europe.

Poland

Poland is using tax incentives to encourage consumption of unleaded gasoline and low-sulfur diesel fuel. More than 80 percent of the diesel fuel currently used is estimated to contain less than 500 ppm sulfur, and 25 percent contains less than 50 ppm sulfur. The excise tax on 500 ppm sulfur fuel is 5 percent less than the tax on diesel fuel with 2,000 ppm, and diesel fuel with a sulfur content of 50 ppm has an excise tax that is 1.5 percent less than that on 500 ppm fuel. The excise tax on unleaded gasoline is 10 percent less than on leaded fuel, but the market penetration of unleaded gasoline has been slower because cars in the country average 10 years old, and only 27 percent are equipped with catalytic converters. In 2000, unleaded gasoline made up 20 percent of total gasoline sales [***117***].

The Polish government is also proposing to commercialize, restructure, and partially privatize the Polish State Railways (PKP) over the period 2001-2003. The reform initiative aims to encourage the development of rail transport services that meet the needs of a market economy, reduce the burden on the state imposed by PKP's heavy losses, and help to prepare the transport system for Poland's entry into the EU. The World Bank approved a loan for the project, which includes severance payments and redeployment services for displaced workers [***118***].

Romania

Romania's transportation infrastructure reflects many years of poor investment. Most roads are in poor condition, and only 25 percent of the road network is modernized. Road density with regard to both population and land area is the lowest among all central and east European countries [***119***]. Car ownership is increasing rapidly, but most of the cars on the road in Romania are old and poorly maintained, running on gasoline that has the highest lead content in Eastern Europe [***120***]. Vehicle ownership in the country increased by 79 percent from 1990 to 1996, and more than 80 percent of the vehicle fleet is gasoline powered. All new vehicles, imported and domestically produced, are now required to have catalytic converters. Romania is planning a complete phaseout of leaded gasoline by 2003 [***121***].

References

1. See, for example, "Strong Dollar, High Oil Price Weaken Demand," *Petroleum Intelligence Weekly* (July 2, 2001), pp. 2-3; "Asian Demand Flat, and May Get Worse," *Petroleum Intelligence Weekly* (July 30, 2001), p. 2.
2. Energy Information Administration, *Short-Term Energy Outlook* (November 2001 and September 2001), web site www.eia.doe.gov/emeu/steo/pub/contents.html.
3. Energy Information Administration, *Short-Term Energy Outlook* (March 2002), web site www.eia.doe.gov/emeu/steo/pub/contents.html.
4. "Delta and Sky Chefs Announce Cuts," *The New York Times* (September 27, 2001).
5. "Congress Allocates $15 Billion To Help the Airline Industry," *The New York Times* (September 22, 2001).
6. "Airbus Freezes Production But Super Jumbo Goes Ahead," *Airwise News* (September 20, 2001), web site http://news.airwise.com/stories/.
7. "Traffic To Grow More Than Capacity at Narita," *Airwise News* (June 6, 2001), web site http://news.airwise.com/stories/.
8. "New Asian Airport Hub Officially Opened at Incheon," *Airwise News* (March 22, 2001), web site http://news.airwise.com/stories/.
9. "Tokyo airports to get new routes to boost flights," *The Japan Times Online* (July 26, 2001), web site http://www.japantimes.co.jp/.
10. "Proposals for New Mexico City Airport Due This Week," *Airwise News* (July 8, 2001), web site http://news.airwise.com/stories/.
11. Massachusetts Institute of Technology and Charles Rivers Associates, *Mobility 2001: Overview*, prepared for the Sustainable Mobility Working Group of the World Business Council for Sustainable Development (North Yorkshire, UK, 2001), p. 2.
12. Natural Resources Defense Council, *Reducing U.S. Oil Dependence: A Real Energy Security Policy* (October 3, 2001), web site www.nrdc.org.
13. Worldwatch Institute, "Hydrogen Rising in Energy Policy Debate," Worldwatch News Release (August 2, 2001), web site www.worldwatch.org.
14. "GM Says Many Green Technologies Ready for Market," *Octane Week*, Vol. 16, No. 42 (October 15, 2001), pp. 4-5.

15. "Squeaky Clean Series: Survey," *The Economist*, Vol. 358, No. 210 (February 10, 2001), p. 17.
16. "Honda Reports Success With New Fuel Cell Vehicle," *Oxy-Fuel News*, Vol. 13, No. 37 (September 24, 2001), p. 9.
17. National Research Council, *Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards*, pp. ES-8 and 3-15.
18. "Fuel Cell Cars Will Need Help To Win in US," *Oil Daily*, Vol. 51, No. 210 (October 30, 2001), p. 1.
19. "Plans for Hydrogen Infrastructure May Be Bush Response to Kyoto," *Clean Air Report*, Vol. 12, No. 17 (August 16, 2001), p. 14.
20. "Replacing Gas With a Gas; Hydrogen-Powered Cars," *The Economist*, Vol. 360, No. 8231 (July 21, 2001), p. 66.
21. "The Fuel Cell's Bumpy Ride," *The Economist*, Vol. 358, No. 8214 (March 24, 2001), p. 39.
22. "GM Says Many Green Technologies Ready for Market," *Octane Week*, Vol. 16, No. 42 (October 15, 2001), pp. 4-5.
23. U.S. Department of Energy, Office of Transportation Technologies, *Future U.S. Highway Energy Use: A Fifty Year Perspective* (Washington, DC, May 3, 2001).
24. "Fuel Economy Figures Are the Worst in 20 Years, EPA Reports," *Octane Week*, Vol. 16, No. 41 (October 12, 2001), p. 2.
25. See, for example, Natural Resources Defense Council, *Reducing U.S. Oil Dependence: A Real Energy Security Policy* (October 3, 2001), web site www.nrdc.org.
26. "Regulatory Activity," *World Fuels Today* (October 12, 2001), p. 2.
27. International Fuel Quality Center, "Overview of Washington, DC Fuel Quality: Policy and Technology Briefing" (October 1, 2001), pp. 5-7.
28. Energy Information Administration, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table A7.
29. "California Transit Agencies Opt for Natural Gas Buses," *LNG Express*, Vol. 11, No. 8 (August 2001), p. 10.
30. International Fuel Quality Center, *Canada Unveils $120 Million Clean Air Initiative, Including Agenda for Clean Fuels, Engines and Vehicles* (Special Report, February 26, 2001), pp. 1-4.
31. Government of Canada, *Action Plan 2000 on Climate Change* (October 2000), pp. 5-6.
32. Natural Resources Canada, *Energy in Canada in 2000* (Ottawa, Ontario, 2000), p. 133.
33. Transport Canada, "Creating a Transportation Blueprint," web site www.tc.gc.ca/en/blueprint.menu.htm (January 15, 2002).
34. D. Apedaile, "Unleash the Potential of Canada's Railways, CPR Tells Transportation Act Review Panel," *Canada NewsWire*, web site www.newswire.ca (December 19, 2000).
35. "Mexico," *World Fuels Today* (October 18, 2001), p. 2.
36. A.G. Bigio et al., *Progress Report 2001: Clean Air Initiative in Latin American Cities* (World Bank, Washington, DC, June 2001), pp. 32-33.
37. Commission of the European Communities, *European Transport Policy for 2010: Time to Decide*, White Paper COM(2001)370 (Brussels, Belgium, September 12, 2001), pp. 25 and 41.
38. D. Jiménez-Beltrán, *Term 2001: Indicators Tracking Transport and Environment Integration in the European Union*, European Environment Agency, Environmental Issue Report No. 23 (Copenhagen, Luxembourg, 2001), p. 31.
39. Petroleum Economics, Ltd., *World Long-Term Oil & Energy Outlook 2000-2015* (London, UK, June 2001), p. 31.
40. International Fuel Quality Center, *EU Taxation Proposal*, Flash Up-Date (September 19, 2001).
41. "British Airways Cuts 7,000 Jobs," *The Washington Post* (September 20, 2001).
42. "Swissair To Resume Some Flights, Thanks to a Bailout," *The New York Times* (October 4, 2001).
43. "European Commission Approves Aid for Airlines," *The New York Times* (October 10, 2001).
44. "Drastic Restructuring of European Airline Industry Foreseen by EU Commissioner," *Airwise News* (October 11, 2001), web site http://news.airwise.com/stories/.
45. "UK Industry Urges Increase in Airport Capacity," *Airwise News* (April 20, 2001), web site http://news.airwise.com/stories/.
46. Mayor of London, "Congestion Charging," web site www.london.gov.uk/mayor/congest (not dated).
47. "Downstream Dilemmas," *Petroleum Economist* (July 2001), pp. 8-9.
48. "German Switch to Low Sulfur Is Ultra Smooth," *Petroleum Intelligence Weekly*, Vol. 40, No. 45 (November 5, 2001), p. 5.
49. M. Smedley, "Germany Sets Out on Big Drive for Natural Gas Vehicles," *World Gas Intelligence*, Vol. 12, No. 32 (October 17, 2001), p. 8.
50. M. Smedley, "Germany Sets Out on Big Drive for Natural Gas Vehicles," *World Gas Intelligence*, Vol. 12, No. 32 (October 17, 2001), p. 10.

51. "Austrian Highway," *World Gas Intelligence*, Vol. 12, No. 34 (October 31, 2001), p. 5.

52. U.S. Central Intelligence Agency, *World Factbook 2001*, web site www.odci.gov/cia/publications/factbook.

53. "New Funds for CNG Fuel Sites," *Financial Times: International Gas Report*, No. 421 (March 2, 2001), p. 28.

54. D. Robertson, "Qantas Leap," *Far Eastern Economic Review*, Vol. 164, No. 40 (October 11, 2001), p. 65.

55. "Automakers Take Rivalry Into Sales of Used Vehicles," *The Nikkei Weekly* (August 6, 2001), p. 11.

56. N.K. Shimbun, *Japan Economic Almanac 2001*, p. 257.

57. "Tokyo Announces Its Stimulus Package," *The New York Times* (October 17, 2001).

58. "LDP Road Councils Hope To Steamroll Koizumi," *Asahi Shimbun* (October 11, 2001), web site http://www.asahi.com/english/politics/.

59. "Tokyo Haneda Expansion Plan," *Airwise News* (March 28, 2001), web site http://news.airwise.com/stories/.

60. "Airlines File Requests To Make Overseas Flight From Haneda," *The Japan Times Online* (January 29, 2001), web site http://www.japantimes.co.jp/.

61. "Traffic To Grow More Than Capacity at Narita," *Airwise News* (June 6, 2001), web site http://news.airwise.com/stories/.

62. "Tokyo Airports To Get New Routes To Boost Flights," *The Japan Times Online* (July 26, 2001), web site www/japantimes.co.jp/.

63. DRI-WEFA, *World Energy Service: Asia/Pacific Outlook* (Lexington, MA, 2001), p. 45.

64. Business Monitor International, *Asia Monitor: China and Northeast Asia*, Vol. 8, No. 9 (September 2001), p. 9.

65. "What's New Around the World: China," *Petroleum Intelligence Weekly*, Vol. 40, No. 43 (October 22, 2001), p. 6.

66. "Asia-Pacific Air Traffic Set To Double," *Airwise News* (September 20, 2001), web site http://news.airwise.com/stories/.

67. "Shanghai Aims High," *Airwise News* (August 23, 2001), web site http://news.airwise.com/stories/.

68. "Gujarat Firms Plan CNG Business," *Financial Times: International Gas Report*, No. 421 (March 2, 2001), p. 24.

69. "Delhi Faces Chaos As Court CNG Bus Deadline Looms," *Financial Times: International Gas Report*, No. 421 (March 2, 2001), p. 1.

70. "Delhi Still Faces Chaos Despite Reprieve," *Financial Times: International Gas Report*, No. 422 (March 30, 2001), p. 5.

71. "Court Relents on CNG Deadline," *Financial Times: International Gas Report*, No. 435 (October 15, 2001), p. 22.

72. "India's CNG Fiasco Could Be Avoided," *World Fuels Today* (October 11, 2001), p. 1 and 5.

73. "GM Agrees To Take Over Daewoo Motor," *The Washington Post* (September 20, 2001).

74. "Korea: A Keen Competitor," *Automotive Design and Production* (February 2001), web site www.autofieldguide.com.

75. Energy Information Administration, *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001), p. 107.

76. Korea Energy Economics Institute, *Yearbook of Energy Statistics 2000* (South Korea, January 2001), pp. 130-131; Cambridge Energy Research Associates, "Asia's Downstream Markets in 2001: Excess Refining Capacity Sets the Tone," *Asia Pacific Oil Watch* (Cambridge, MA, Winter 2001), p. 9; and Korea Energy Economics Institute, *Korea Energy Review Monthly* (June 2001), p. 8.

77. Korea Energy Economics Institute, "Fourfold Rise Due for Tax on LPG," News Briefs in Korea, web site www.keei.re.kr/keei/index_us.html (June 25, 2001).

78. "Inchon Fees Will Be Higher," *Airwise News* (February 27, 2001), web site http://news.airwise.com/stories/.

79. "Thailand Begins Selling Ethanol at the Pump, Eyes Tax Breaks," *Oxy-Fuel News*, Vol. 13, No. 3 (January 22, 2001), p. 2.

80. A.M. Ruff, "The Good Oil," *Far Eastern Economic Review*, Vol. 164, No. 33 (August 23, 2001), p. 37.

81. S.W. Crispin, "Breathtaking Results in Bangkok," *Far Eastern Economic Review*, Vol. 164, No. 42 (October 25, 2001), pp. 44-46.

82. Energy Information Administration, "Country Analysis Brief: Indonesia: Environmental Issues," web site www.eia.doe.gov (October 2001).

83. "Indonesia," *World Fuels Today* (October 22, 2001), p. 2.

84. L. Hopkinson and S. Skinner, *Cleaner Vehicles and Fuels: The Way Forward* (Civic Exchange, August 2001).

85. A.G. Bigio et al., *Progress Report 2001: Clean Air Initiative in Latin American Cities* (World Bank, Washington, DC, June 2001), p. 4.

86. Worldwatch Institute, "Curbing Sprawl to Fight Climate Change," Worldwatch News Release (June 28, 2001), web site www.worldwatch.org.

87. International Fuel Quality Center, *Current Latin American Fuel Quality Situation* (July 25, 2001), pp. 8 and 10.

88. U.S. Central Intelligence Agency, *World Factbook 2001*, web site www.odci.gov/cia/publications/factbook/.

89. U.S. Department of State, "Brazil: Consular Information Sheet," *Travel Warnings and Consular Information Sheets*, web site www.travel.state.gov (October 9, 2001).

90. Energy Information Administration, "Country Analysis Brief: Brazil: Environmental Issues," web site www.eia.doe.gov (July 2001).

91. Energy Information Administration, "Country Analysis Brief: Brazil: Environmental Issues," web site www.eia.doe.gov (July 2001).

92. "Brazil's Cardoso Slates Gasoline Price Cuts," *Oil Daily* (March 30, 2001), p. 6.

93. "PDV Preps for Huge Brazilian Retail Expansion," *Oil Daily* (September 17, 2001), p. 4.

94. Energy Information Administration, "Country Analysis Brief: Argentina," web site www.eia.doe.gov (October 2001).

95. U.S. Central Intelligence Agency, *World Factbook 2001*, web site www.odci.gov/cia/publications/factbook/.

96. "Investing in Argentina: Transportation and Communications: Overland Transport," Fundacion Invertir Argentina, web site www.invertir.com (not dated).

97. Energy Information Administration, "Country Analysis Brief: Argentina: Environmental Issues," web site www.eia.doe.gov (July 2001).

98. A.G. Bigio et al., *Progress Report 2001: Clean Air Initiative in Latin American Cities* (World Bank, Washington, DC, June 2001), p. 22.

99. International Fuel Quality Center, *The Governments Argentina & Brazil Legislate New Fuel Specifications for Their Respective Countries* (November 9, 2001), p. 2.

100. "Argentina," *World Fuels Today* (November 27, 2001), p. 2.

101. M. Smedley, "Germany Sets Out on Big Drive for Natural Gas Vehicles," *World Gas Intelligence*, Vol. 12, No. 32 (October 17, 2001), p. 8.

102. "Investing in Argentina: Transportation and Communications: Overland Transport," Fundacion Invertir Argentina, web site www.invertir.com (not dated).

103. "Investing in Argentina: Transportation and Communications: Water Transport," Fundacion Invertir Argentina, web site www.invertir.com (not dated).

104. "Aerolineas Argentinas Flies Again," *Airwise News* (November 9, 2001), web site http://news.airwise.com/stories/.

105. "Transport: Roads," Saudi Arabian Information Resource, web site www.saudinf.com (not dated).

106. Energy Information Administration, "Country Analysis Brief: Saudi Arabia: Environmental Issues," web site www.eia.doe.gov (July 2001).

107. "Transport: Air Transport," Saudi Arabian Information Resource, web site www.saudinf.com (not dated).

108. "Dubai Airport Hits New Heights," *Airwise News* (July 16, 2001), web site http://news.airwise.com/stories/.

109. "Dubai Plans Major Airport Develpments," *Airwise News* (November 5, 2001), web site http://news.airwise.com/stories/.

110. F.N. Nyangaga, "Reforming Road Management in Sub-Saharan Africa," *Africa Transport Technical Note*, No. 32 (World Bank, Washington, DC, March 2001), p. 1.

111. T. Gustafson, *Capitalism Russian-Style* (Cambridge, UK: Cambridge University Press, October 1999), p. 178.

112. "A Survey of Russia: Waiting for the Crunch," *The Economist*, Vol. 360, No. 8231 (July 21, 2001), p. 12.

113. T. Gustafson, *Capitalism Russian-Style* (Cambridge, UK: Cambridge University Press, October 1999), pp. 221-222.

114. K. Crane, *Review and Outlook for the Former Soviet Republics* (Washington, DC: PlanEcon, Inc., October 2001), pp. i-iii.

115. J. Simpson, Editor, *Requirements and Framework for Environment and Transport Telematics Implementation: Assessment of the State of the Transport System* (Regional Environmental Center for Central and Eastern Europe, Co-ordinated Action for Pan-European Transport and Development, August 1999), web site www.rec.org.

116. J. Simpson, Editor, *Requirements and Framework for Environment and Transport Telematics Implementation: Assessment of the State of the Transport System* (Regional Environmental Center for Central and Eastern Europe, Co-ordinated Action for Pan-European Transport and Development, August 1999), web site www.rec.org.

117. International Fuel Quality Center, *Poland's Fuel Quality and Policy Developments* (February 2001).

118. World Bank, "Poland: World Bank Loan To Help Restructure Polish State Railways Signed Today," Press Release No. 2001/350/ECA (May 31, 2001).

119. J. Simpson, Editor, *Requirements and Framework for Environment and Transport Telematics Implementation: Country Reports: Romania* (Regional Environmental Center for Central and Eastern Europe, Co-ordinated Action for Pan-European Transport and Development, August 1999), web site www.rec.org.

120. Energy Information Administration, "Country Analysis Brief: Romania: Environmental Issues," web site www.eia.doe.gov (September 2000).

121. Sofia Initiative on Local Air Quality, *Phase-out of Leaded Gasoline* (Szentendre, Hungary: Regional Environmental Center for Central and Europe, May 1998), Section 3.2, pp. 1 and 3, Section 5.4, p. 4, web site www.rec.org.

Environmental Issues and World Energy Use

In the coming decades, global environmental issues could significantly affect patterns of energy use around the world. Any future efforts to limit carbon emissions are likely to alter the composition of total energy-related carbon emissions by energy source.

Global climate change is a wide-reaching environmental issue that has received increased attention in recent years. Carbon dioxide, one of the most prevalent greenhouse gases in the atmosphere, has two major anthropogenic (human-caused) sources: the 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 since pre-industrial times. Because estimates indicate that approximately 80 percent all anthropogenic carbon dioxide emissions currently come from fossil fuel combustion, world energy use has emerged at the center of the climate change debate [***1***].

Global Outlook for Carbon Dioxide Emissions

The *International Energy Outlook 2002* (*IEO2002*) 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 *IEO2002* reference case, global carbon dioxide emissions are expected to grow more rapidly over the projection period than they did during the 1990s. An 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 25). The steepest rates of improvement are, for the most part, expected to occur 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

Table 25. Carbon Intensities for Selected Countries and Regions, 1999-2020
(Metric Tons Carbon Equivalent per Thousand 1997 Dollars of GDP)

Country or Region	1999	2005	2010	2020	Annual Percent Change, 1999-2020
United States	168	159	146	124	-1.4
Canada	214	194	178	155	-1.5
Mexico	230	234	218	185	-1.0
United Kingdom	109	104	96	81	-1.4
France	72	68	62	56	-1.2
Germany	105	98	90	78	-1.4
Australasia	223	203	187	159	-1.6
Former Soviet Union	1,068	900	785	589	-2.8
Eastern Europe	558	482	411	305	-2.8
China	645	555	493	392	-2.3
India	511	457	403	315	-2.3
South Korea	218	201	177	142	-2.0
Brazil	108	100	100	94	-0.6
Turkey	268	253	229	191	-1.6

Sources: **1999:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **2005-2020:** EIA, World Energy Projection System (2002).

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.

The developing Asian countries of China and India are also expected to enjoy a fairly rapid improvement in carbon intensity 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 *IEO2002* reference case, but their annual GDP growth is projected to average 6.6 percent, compared with an expected 4.4-percent annual rate of increase in fossil fuel use from 1999 to 2020.

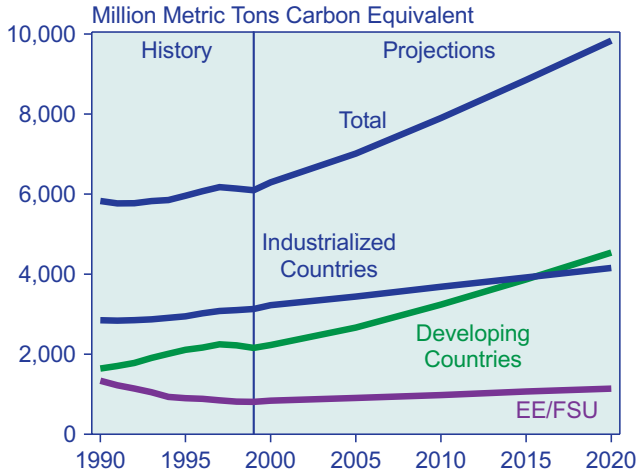
In 1999, carbon dioxide emissions from industrialized countries accounted for 51 percent of the global total, followed by developing countries at 35 percent and the EE / FSU at 13 percent. By 2020, developing countries are projected to account for the largest share of world carbon dioxide emissions, at 46 percent, followed by the industrialized world at 42 percent and the EE / FSU at 12 percent. The *IEO2002* projections indicate that carbon dioxide emissions from developing countries could surpass those from industrialized countries around 2015 (Figure 88).

In the industrialized world, almost one-half of all energy-related carbon dioxide emissions in 1999 came from oil use, followed by coal at 30 percent (Figure 89). 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 2020, the share of natural-gas-related emissions is expected to be approximately equal to that of coal at 26 percent.

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. No new nuclear plants are expected to be constructed in the United States by 2020, 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.

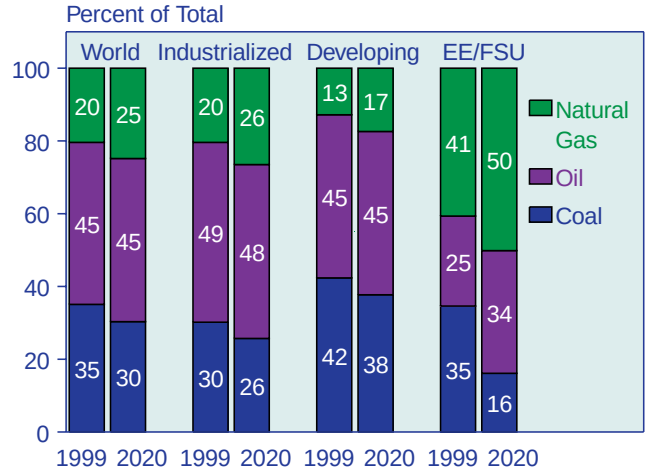
With the exception of Australia, most other industrialized countries rely much less heavily on coal to meet domestic energy needs than does the United States. In Western Europe, coal consumption is projected to continue to decline over the forecast period as natural gas consumption, particularly for 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

Figure 88. World Carbon Dioxide Emissions by Region, 1990-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

Figure 89. Shares of World Carbon Dioxide Emissions by Region and Fuel Type, 1999 and 2020



Sources: **1999:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **2020:** EIA, World Energy Projection System (2002).

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 fully offset the drop in nuclear energy production in these regions.

In the transitional economies of the EE/FSU region, the majority of energy-related carbon dioxide emissions currently 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 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 47 percent and 34 percent, respectively, by 2020.

With further restructuring of the coal mining industries in Poland and the Czech Republic, declines in coal production and consumption are expected to continue. On the other hand, natural gas consumption in Eastern Europe is expected to increase significantly, driven in part by the need for many countries to meet the strict environmental standards required for membership in the European Union (EU). As a result of the projected changes in the energy mix, Eastern Europe's carbon intensity is expected to decline more than in any other world region over the forecast period. However, the decline in Eastern Europe's carbon intensity is not expected to keep pace with the expected growth in its total energy consumption. Consequently, annual carbon dioxide emissions in the region are expected to increase by nearly 26 percent between 1999 and 2020.

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, *IEO2002* does not include the combustion of biomass fuels in its coverage of current or projected energy consumption and associated carbon dioxide emissions, except for the United States.

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. Second only to developing Asia in terms of projected growth in energy consumption and carbon dioxide emissions, is Central and South America. Many countries in the region, most notably Brazil, have relied heavily on hydropower to provide the majority of their electricity. Natural gas is expected to take on an increasing share of the energy mix in Central and South America over the forecast period, however, as the countries continue their efforts to lessen dependence on hydropower by tapping into the region's large natural gas reserves. As a result of the expected change in the region's fuel mix, coupled with an increase in overall energy demand, carbon dioxide emissions from Central and South America are expected to more than double between 1999 and 2020.

Future levels of energy-related carbon dioxide emissions in all regions are likely to differ significantly from *IEO2002* projections if measures to mitigate 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 future fuel use worldwide. Because the Kyoto Protocol has not yet come into force, the *IEO2002* projections do not reflect the potential effects of the treaty or of any other proposed climate change policy measures.

Issues in Energy-Related Emissions Policy

International Climate 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 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" [***2***]. The most ambitious proposal coming out of subsequent conferences 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 time period. Quantified emissions targets are differentiated by country. [26]

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 four "flexibility mechanisms" (sometimes called "Kyoto 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. This trade would lower the seller's allowable emissions level by 10 million metric tons of carbon equivalent and raise the buyers' allowances by the same amount in total.

- *Joint fulfillment* allows Annex I countries that are members of an established regional grouping to achieve their reduction targets jointly, provided that their aggregate emissions do not exceed the sum of their combined Kyoto commitments. For example, EU countries have adopted a burden-sharing agreement that reallocates the aggregate Kyoto emission reduction commitment for the EU among the member countries [***3***].

- *The clean development mechanism* (CDM) allows Annex I countries, either through the government or a legal entity, 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 emissions reduction commitments. The CDM, in principle, redistributes emission reductions from developing country parties to Annex I parties.

- *Joint implementation* (JI) is similar to the clean development mechanism except that 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 gases emissions and smaller reductions of carbon dioxide, or vice versa, in order to meet its entire 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 or remove carbon dioxide and other greenhouse gases from the atmosphere via terrestrial "sinks" (trees, plants, and soils) are also allowed as "reductions" under the Protocol. The extent to which each Annex I party makes use of sinks and the mechanisms for counting the offsets will influence the amount of 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. Some of the more contentious topics in the negotiation process have been the regime for enforcement of emission reduction commitments, the treatment of sinks, and rules for meeting national emissions targets via the Kyoto mechanisms. These issues were scheduled to be resolved at the November 2000 COP-6 meeting in The Hague, the Netherlands, but the meeting ended without agreement, and delegates reconvened in Bonn, Germany, in July 2001 to continue the COP-6 proceedings.

The main agreements reached at Bonn 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 upper bounds; afforestation and reforestation projects can be eligible for the CDM; and no quantitative limits can be placed on emissions credit trading as a means of meeting the Kyoto commitments. The Bonn agreement also calls for 2 percent of the certified emissions reductions issued for any CDM project to go toward a fund for climate change adaptation projects in developing countries. The procedures and institutions needed to make the Kyoto Protocol fully operational were finalized by delegates at COP-7, held in Marrakech, Morocco, from October 29 through November 9, 2001.

Although the United States was present at COP-6 and COP-7, it did not take an active role in the negotiations. In March 2001, the United States announced that it would not support the Kyoto Protocol. As it currently stands, the only Annex I countries that have ratified the

[26]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.

Kyoto Protocol are the Czech Republic and Romania.[27] The 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. The United States had the largest share of Annex I emissions in 1990, at 34.6 percent. Even without participation from the United States, however, the Protocol still could enter into force for the other signatories.

The *IEO2002* 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 12 percent in 2010 (Figure 90). 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 2,579 million metric tons of carbon equivalent in 2010, or 27 percent less than their projected baseline emissions.[28] On the other hand, energy-related carbon dioxide emissions from the group of transitional Annex I countries have been decreasing throughout the 1990s as a result of economic and political crises in the EE/FSU. Baseline emissions from the transitional Annex I countries are projected to be 38 percent below their combined Kyoto Protocol reduction target by 2010.

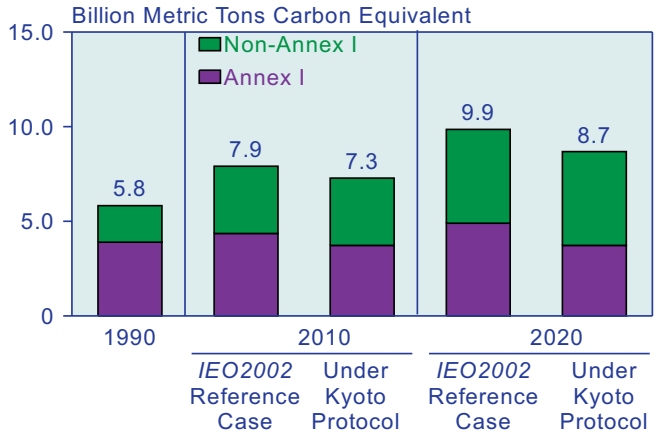
Greenhouse Gas Emissions Trading

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.

One framework for emissions trading is "cap and trade," whereby a regulatory authority establishes a permanent cap on aggregate emissions for a group of emitters. The cap may, for example, be set at a fraction of the historic emissions from the group of participants. The cap is divided into a set number of allowances, each of which gives 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 one metric ton of carbon dioxide equivalent. Once distributed among the participants, the allowances may be bought, sold, or (possibly) banked for future use. At the end of each compliance period, each participant must 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 during the 1990s to achieve reductions in stationary-source sulfur dioxide emissions.

Emissions trading can also be based on concepts other than cap and trade. An offsets or credit-based emissions trading system can incorporate capped and non-capped industries and entities that trade voluntarily created, permanent emissions reductions that are legally recognized by a regulator. This system essentially allows entities with emissions increases to obtain offsetting reductions from other entities. Other trading variants include baseline emissions trading systems, which allow entities to reduce emissions below a level that would otherwise occur under business as usual, and then trade the emissions reductions. Rate-based emissions trading focuses on the emission per unit of output rather than absolute emissions; entities that improve their efficiency

Figure 90. Carbon Dioxide Emissions in Annex I and Non-Annex I Nations Under the Kyoto Protocol, 2010 and 2020



Sources: **1990:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **2010 and 2020:** World Energy Projection System (2002).

[27]The following 49 Parties to the Convention have ratified, accepted, acceded, or approved the Protocol as of March 6, 2002: Antigua and Barbuda, Argentina, Azerbaijan, Bahamas, Bangladesh, Barbados, Benin, Bolivia, Burundi, Colombia, Cook Islands, Cyprus, Czech Republic, Dominican Republic, Ecuador, El Salvador, Equatorial Guinea, Fiji, Gambia, Georgia, Guatemala, Guinea, Honduras, Jamaica, Kiribati, Lesotho, Malawi, Maldives, Malta, Mauritius, Mexico, Micronesia, Mongolia, Morocco, Nauru, Nicaragua, Niue, Palau, Panama, Paraguay, Romania, Samoa, Senegal, Trinidad and Tobago, Turkmenistan, Tuvalu, Uruguay, Uzbekistan, and Vanuatu.

[28]The Kyoto Protocol emission targets are based on the average of emissions between 2008 and 2012—the first commitment period. Because 2010 is the midpoint of the first commitment period, it is commonly used as the reference year for calculating emissions reductions under the Kyoto agreement.

beyond the target levels can trade the excess improvement with other companies.

In October 2001, the EU released a final proposal for establishing its own internal greenhouse gas emissions trading system [*5*]. The first 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 requires 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 trading scheme may be extended to include all greenhouse gases after the first phase.

The EU member states would determine the quantity of allowances to be issued in each phase. During the first phase, with no legally binding limits on greenhouse gas emissions, allowances would be distributed free of charge. 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 but not across phases.

The EU proposal was designed to be compatible with the international emissions trading under the Kyoto framework and with some market-based instruments for emission reductions being developed in individual countries, such as tradable renewable energy certificates. Currently, Denmark is the only country that has instituted a mandatory cap and trade system to reduce carbon dioxide emissions from electricity producers. A cap of 22 million tons of carbon dioxide was set for 2001; the cap will decline by 1 million metric tons per year. The trading system became operational in April 2001 and will run through 2003. Free allowances were allocated to eight firms, based on their emissions during the 1994-1998 period. Should the program be extended, its allowances are likely to be compatible with the proposed EU trading scheme.

The compatibility of the EU proposal with the voluntary emissions trading program in the United Kingdom that is set to begin in April 2002 is more questionable. The programs differ in several aspects, 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, or by carrying out a project that results in a verified emissions reduction. Companies earn tradable allowances for carbon dioxide computed either from their targets or from the project-based reduction. At this point, it is unclear to what extent allowances earned under the UK scheme could be traded under the proposed EU scheme.

Abating Other Energy-Related Emissions

Many countries currently have policies or regulations in place that limit energy-related emissions other than carbon dioxide. Criteria pollutants such as sulfur oxides and nitrogen oxides are also emitted as a result of fossil fuel combustion, contributing to a variety of health and environmental problems that include acid rain, deterioration of soil and water quality, and human respiratory illnesses. Nitrogen oxide emissions additionally contribute to the formation of ground-level ozone (smog). Furthermore, criteria pollutants indirectly affect the global climate by reacting with other chemical compounds in the atmosphere to form greenhouse gases or, in the case of sulfur dioxide, by affecting the absorptive characteristics of the atmosphere.

To date, the measures taken to mitigate criteria pollutant emissions have been focused primarily on the main sources. Fossil fuel combustion for electricity generation, particularly coal-fired power, represents the largest source of sulfur dioxide emissions in many countries. Other significant energy-related sources include fuel combustion for manufacturing industries, vehicles, and petroleum refining. Nitrogen oxides are emitted as a result of fossil-fuel-based electricity generation, although oil use for road transportation is generally the single largest source.

With the tightening of emissions limitations on combustion plants, sulfur dioxide emissions fell in many industrialized countries during the 1990s. In Europe, the shift from coal to natural gas for electricity production (most notably in the United Kingdom and Germany) also contributed to the 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.

Despite the imposition of emissions regulations, nitrogen oxide emissions rose during the 1990s in most 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 actually led to a gradual drop in nitrogen oxide emissions [*6*]. To continue combating ground-level ozone formation, several countries plan to tighten their emissions standards for new vehicles over the

coming years (Table 26). Limits on the sulfur content of gasoline and diesel are also being required in order to ensure the effectiveness of the emissions control technologies used to meet the new vehicle standards (Table 27).

In the United States, the main initiatives to reduce emissions of criteria pollutants stem from the 1970 Clean Air Act—the comprehensive Federal law that regulates air emissions from stationary and mobile sources. Subsequent amendments to the Clean Air Act imposed emissions standards and requirements that the best available control technologies be used for new sources. Largely intended to address specific environmental problems, the Clean Air Act Amendments of 1990 (CAAA90) set emissions reduction goals for particular air pollutants and designated stricter emissions standards across a wider range of sources.

To control acid deposition, Title IV of CAAA90 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 sulfur dioxide program specifies a two-phase reduction in emissions from fossil-fired electric power plants greater than 25 megawatts in output 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 emissions at 8.95 million metric tons by 2010.[29] Individual plant operators may reduce

Table 26. 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 Direcetive 99/96/EC, Official Journal L 44 (February 16, 2000). **Australia:** Department of Transpoprt and Regional Services, "Vehicle Emission Australian Design Rules (ADRs)" (August 7, 2001).

Table 27. Future Sulfur Content Limits on Motor Fuels in Select 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]	As of 1/1/2002
					150 ppm[b]	As of 1/1/2002
					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
					50 ppm	As of 1/1/2006

[a]For unleaded petrol and lead replacement petrol.
[b]For premium unleaded petrol.
[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). **Australia:** Attorney General's Department, Office of Legislative Drafting, "Fuel Standards Quality Act of 2000: Fuel Standards (Diesel and Petrol)" (October 8, 2001).

[29]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.

their emissions through any combination of strategies, including installation of scrubbers, switching to low sulfur fuels, and emissions allowance trading and banking. Emissions reductions under the nitrogen oxide program, which targets certain coal-fired utility boilers, are also scheduled according to two phases. As with the sulfur dioxide program, the Phase II nitrogen oxide limits 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.

To reduce ozone formation, the U.S. Environmental Protection Agency has promulgated a multi-State summer season cap on power plant nitrogen oxide emissions that will take effect in 2004. The rules, commonly referred to as the "NO_x SIP Call," require abatement efforts greater than those required to comply with the nitrogen oxide limits under Title IV of CAAA90. 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 both the Federal and State levels. Power plant operators may also face requirements to reduce mercury and carbon dioxide emissions. At present, neither the future reductions nor the timing for compliance is known for any of these airborne emissions (see box on page 171).

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 will be phased in starting in 2004, marking the first time that both cars and light-duty trucks will be subject to the same national pollution control system in the United States. The current emissions standards for heavy-duty vehicles, which have been in place since 1998, will be further tightened in two stages: 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 [***7***, ***8***].

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 [***9***, ***10***]. The new gasoline sulfur standard will be phased in between 2004 and 2007, in order to ease the transition for domestic refineries. By June 1, 2006, refiners and importers must produce highway diesel according to the new standard, although the law incorporates a phase-in period and hardship provisions for small refiners through May 2010.

In Canada, efforts to abate sulfur dioxide emissions have focused on the seven easternmost provinces, where acid rain has already begun to damage sensitive ecosystems.[30] 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. Some provinces extended the emissions cap through 2000 and beyond. Recently, further sulfur dioxide emission reduction targets were announced by Ontario, Quebec, New Brunswick, and Nova Scotia for the 2002-2015 time frame.

Addressing the problems of acid rain and ground-level ozone in Canada has required cooperation from the United States, given the transboundary flows 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. Recently, new measures at federal and provincial levels in Canada were enacted to reduce their nitrogen oxide emissions. Starting in 2007, fossil fuel 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.

Until recently, Canada's emission regulations for light-duty vehicles were aligned with those of the United States for the 1998 model year. The Canadian government has now reached an agreement with vehicle manufacturers to equip new light-duty vehicles and trucks sold with the same emissions control and monitoring equipment needed to meet the U.S. Federal emissions standards for the 2001-2003 model years. Canada will also require a diesel fuel sulfur cap of 15 parts per million by June 2006, mirroring the U.S. highway diesel regulation.

In Europe, efforts to limit aggregate emissions of sulfur dioxide and nitrogen oxides were first coordinated under the 1979 United Nations/European Economic Commission 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 and nitrogen oxides. 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

[30]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.

Multiple Emissions Controls in U.S. Electricity Markets

Electric power plant operators in the United States may face new requirements to reduce emissions of sulfur dioxide (SO_2) and nitrogen oxides (NO_x) beyond the levels called for in current regulations. They could also face requirements to reduce carbon dioxide (CO_2) and mercury (Hg) emissions. At present neither the future reductions nor the timing for compliance is known for any of these airborne emissions. Given these uncertainties, compliance planning is difficult for plant owners.

Until recently, each of these environmental issues was addressed through separate regulatory programs, many of which are undergoing modification. To control acidification, the Clean Air Act Amendments of 1990 (CAAA90) required operators of electric power plants to reduce emissions of SO_2 and NO_x. Phase II of the SO_2 reduction program—lowering allowable SO_2 emissions to an annual national cap of 8.95 million tons—became effective on January 1, 2000.[a] More stringent NO_x emissions reductions are required under various Federal and State laws taking effect from 1997 through 2004. For example, in 1997 the U.S. Environmental Protection Agency (EPA) issued new 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. States are also beginning efforts to address visibility problems (regional haze) in national parks and wilderness areas throughout the country. Because electric power plant emissions of SO_2 and NO_x contribute to the formation of regional haze, States could require that these emissions be reduced to improve visibility in some areas. In the near future, it is expected that new national ambient air quality standards for ground-level ozone and fine particulates may necessitate additional reductions in NO_x and SO_2 emissions.

To reduce ozone formation, the EPA has promulgated a multi-State summer season cap on power plant NO_x emissions that will take effect in 2004. Emissions that lead to fine particles (less than 2.5 microns in diameter), their impacts on health, and the level of reductions that might be required are currently being studied. Fine particles are associated with power plant emissions of NO_x and SO_2, and further reductions in NO_x and SO_2 emissions could be required by as early as 2007 in order to reduce emissions of fine particles. In addition, the EPA decided in December 2000 that Hg emissions must be reduced; proposed regulations will be developed over the next 3 years, possibly as part of a multi-emissions reduction strategy. Further, if the United States decided that emissions of greenhouse gases need to be mitigated, energy-related CO_2 emissions would also have to be reduced.[b]

Because the timing and levels of emission reduction requirements under the new standards are uncertain, compliance planning is complicated. It can take several years to design, license, and construct new electric power plants and emission control equipment, which may then be in operation for 30 years or more. As a result, power plant operators must look into the future to evaluate the economics of new investment decisions.

The potential for new emissions standards with different timetables adds considerable uncertainty to investment planning decisions. An option that looks attractive to meet one set of SO_2 and NO_x standards may not be attractive if further reductions are required in a few years. Similarly, economical options for reducing SO_2 and NO_x today may not be the optimal choice in the future if Hg and CO_2 emissions must also be reduced.

Further complicating planning, some investments capture multiple emissions simultaneously, such as advanced flue gas desulfurization equipment that reduces SO_2 and Hg, making such investments more attractive under some circumstances. As a result, power plant owners currently are wary of making investments that may prove unwise a few years hence. Aware of these difficulties, both the previous and current Congresses have proposed legislation that would require simultaneous reductions of multiple emissions.

There have been three Congressional requests to the Energy Information Administration (EIA) for analyses of proposed legislation for reductions of multiple emissions. The Subcommittee on National Economic Growth, Natural Resources, and Regulatory Affairs of

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[a]A description of the legislation is available at web site www.epa.gov/oar/caa/contents.html.

[b]On February 14, 2002, President Bush proposed that U.S. businesses voluntarily track and reduce their output of greenhouse gases. He proposed that goals for reductions be tied to the growth rate of the economy. It is believed that this approach will minimize the loss in economic efficiency. The President''s proposal for multiple emissions controls would cut annual sulfur dioxide emissions by 73 percent, from current emissions of 11 million tons to caps of 4.5 million tons in 2010 and 3 million tons in 2018. It would cut emissions of nitrogen oxides by 67 percent, from current emissions of 5 million tons to caps of 2.1 million tons in 2008 and 1.7 million tons in 2018. Mercury emissions would be reduced by 69 percent, from current emissions of 48 tons to caps of 26 tons in 2010 and 15 tons in 2018. The President's proposal for control of multiple emissions is available at web site www.whitehouse.gov/news/releases/2002/02/clearskies.html.

Multiple Emissions Controls in U.S. Electricity Markets (Continued)

the U.S. House of Representatives Committee on Government Reform[c] asked EIA to "analyze the potential costs of various multi-emissions strategies to reduce the air emissions from electric power plants."[d] The Subcommittee requested that EIA examine cases with alternative NO_x, SO_2, CO_2, and Hg emission reductions, with and without a renewable portfolio standard (RPS) requiring a specified portion of all electricity sales to come from generators that use nonhydroelectric renewable fuels.

In the cases specified by the Subcommittee, emissions of NO_x and SO_2 were to be reduced to 75 percent below 1997 levels beginning in 2002, and compliance was to be achieved by 2008. CO_2 emissions were required to be reduced to 1990 levels by 2008 and 7 percent below 1990 levels by 2012. Hg emissions were to be reduced by 90 percent from 1997 levels by 2008. The RPS was targeted to reach 20 percent by 2020. The analysis examined the impacts of these requirements both for individual emissions and for all emissions taken together.

In a second study, requested by Senators Smith, Voinovich, and Brownback, EIA was asked to examine the costs of different multi-emissions reduction strategies for NO_x, SO_2, and Hg. The Senators also requested an analysis of the potential costs of requiring power suppliers to acquire offsets for any increases in CO_2 emissions beyond the levels currently expected for 2008. The request called for 50- to 75-percent reductions in NO_x below 1997 levels, 50- to 75-percent reductions in SO_2 emissions below full implementation of CAAA90 Title IV, and 50- to 75-percent reductions in Hg emissions below 1999 levels, with half the reductions to be achieved by 2007 and the full reductions to occur by 2012. The emissions reduction programs, covering all electricity generators other than cogenerators producing both electricity and useful thermal output, were patterned after the SO_2 allowance program created in the CAAA90. One-half of the reductions in Hg emissions were to come from site-specific reductions.[e]

A third analysis, requested by Senators Jeffords and Lieberman, was to examine the potential impacts of limits on SO_2, NO_x, CO_2, and Hg emissions from electricity generators.[f] Using 2002 as a start date for emissions reductions, the request specified that, by 2007, NO_x emissions from electricity generators were to be reduced to 75 percent below 1997 levels, SO_2 emissions to 75 percent below the full implementation of the Phase II requirements under CAAA90 Title IV, Hg emissions to 90 percent below 1999 levels, and CO_2 emissions to 1990 levels. It was assumed that the emissions limits would be applied to all electricity generators, excluding cogenerators. This analysis examined the impacts of the specified limits or "caps" on electricity-sector emissions of SO_2, NO_x, Hg, and CO_2 under four scenarios with different assumptions about technology cost and performance, energy policies, and consumer behavior.

Emission caps imposed were assumed to be implemented under a "cap and trade" system patterned after the SO_2 CAAA90 allowance program.[g] All electricity generators, excluding cogenerators, were assumed to be covered by the emissions caps. Electricity generators were assumed to behave competitively, incorporating the costs of emissions allowances in their electricity bid prices. The cases included all energy laws and regulations in effect as of July 1, 2000, including the NO_x and SO_2 regulations established in the CAAA90, plus the new appliance efficiency standards announced in January 2001, as modified by the Bush Administration.

There are common findings across the three Congressional analyses of multiple emissions strategies. Generally, the costs of implementing multiple emissions strategies vary with the stringency of the reductions required and, to a lesser extent, the time frame for compliance. The costs of multiple emissions strategies also vary widely depending on whether CO_2 controls are included or excluded. The impacts of multiple emissions controls for SO_2, NO_x, and Hg that exclude CO_2

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[c]In the 107th Congress, this subcommittee was renamed the Subcommittee on Energy Policy, Natural Resources and Regulatory Affairs.

[d]Energy Information Administration, *Analysis of Strategies for Reducing Multiple Emissions from Electric Power Plants: Sulfur Dioxide, Nitrogen Oxides, Carbon Dioxide, and Mercury and a Renewable Portfolio Standard*, SR/OIAF/2001-03 (Washington, DC, July 2001), web site www.eia.doe.gov/oiaf/servicerpt/epp/index.html.

[e]Energy Information Administration, *Reducing Emissions of Sulfur Dioxide, Nitrogen Oxides, and Mercury from Electric Power Plants*, SR/OIAF/2001-04 (Washington, DC, September 2001), web site www.eia.doe.gov/oiaf/servicerpt/mepp/pdf/sroiaf(2001)04.pdf.

[f]Energy Information Administration, *Analysis of Strategies for Reducing Emissions from Electric Power Plants with Advanced Technology Scenarios*, SR/OIAF/2001-05 (Washington, DC, October 2001), web site www.eia.doe.gov/oiaf/servicerpt/eppats/pdf/sroiaf(2001)05.pdf.

[g]Numerous policy instruments are available, including taxes, maximum achievable control technology, no-cost allowance allocation with cap and trade, allowance auction with cap and trade, and generation performance standard allowance allocation with cap and trade. Each of these options would have different price and cost impacts.

emissions reductions. To date, Luxembourg is the only country that has ratified the Gothenburg Protocol. Parallel to CLRTAP developments, the EU has been considering other proposals for national emissions ceilings for sulfur dioxide, nitrogen oxides, volatile organic compounds, and ammonia at levels that are stricter than those set under the Gothenburg Protocol [***11***].

Specific measures for abating sulfur dioxide and nitrogen oxide emissions are already defined in a number of existing EU directives. The Large Combustion Plant Directive of 1988 and subsequent amendments impose emissions limits for sulfur dioxide and nitrogen oxides on existing and new plants with a rated thermal input capacity greater than 50 megawatts. For plants licensed before July 1, 1987, the Directive places a gradually declining ceiling (cap) on total annual emissions of each pollutant. The ceiling values are differentiated by country. The Directive does not stipulate how the emissions reductions are 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, face uniform emissions limit values, which are set according to plant capacity size and fuel type. The EU is considering a proposal to tighten the air pollution limits from new combustion plants in line with the substantial technical progress that has been made in this sector. The proposed emission limits for new plants are twice as strict as the current limits [***12***].

Nitrogen oxide 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 so-called "Euro 3" emissions standards 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 all of its "city diesel" to meet the same sulfur standard (50 parts per million) required by the EU in 2005. Currently, the EU is considering a proposal that includes the mandatory introduction of sulfur-free motor fuels[31] by January 1, 2005, and a complete ban on all non-sulfur-free fuels by January 1, 2009 [***13***, ***14***]. The implementation of the measure would coincide with the introduction of Euro 4 vehicles in the European market.

In Australia, measures to reduce sulfur dioxide and nitrogen oxide emissions have been focused primarily on the transportation sector. Although Australia relies heavily on domestic coal for electricity generation, it has a lower sulfur content than the coal produced in most other countries. The ambient air quality concentrations of sulfur dioxide in most Australian towns and cities usually have remained well within a level that the government deems to be safe. Because of the health risks associated with high concentrations of nitrogen dioxide, particular in urban centers, the Australian government has begun to implement measures to reduce current and

Multiple Emissions Controls in U.S. Electricity Markets (Continued)

are significantly less than the results discussed here where CO_2 controls are included.

The higher the requirement to reduce CO_2 emissions and the shorter the time frame for the reductions, the higher the costs are expected to be. For example, when the emission reduction requirements are increased from 75 percent in the analysis that excludes CO_2 limits to 90 percent in the Jeffords-Lieberman reference case, which includes CO_2 limits, the projected cumulative resource costs (including fuel, operations and maintenance, and investment costs) to achieve them increase from $89 billion to $177 billion.

Higher resource costs and higher electricity prices to consumers are projected in all the multiple emissions cases analyzed. Electricity prices increase as a result of investments in emission control technologies, purchases of allowances, construction of new generating equipment to replace existing equipment, and higher fuel costs.

In all the analyses, higher electricity prices result in part from increases in natural gas consumption and the attendant high prices for natural gas in the emissions limits cases over the prices that would be expected without emissions limits. Natural gas consumption increases because it has lower emissions than other fossil fuels, particularly coal. Nuclear power and renewable energy sources also have lower emissions than either coal or natural gas. When emissions limits are assumed, the use of coal as a fuel for electricity generation is less desirable, and as a result consumption declines. In most of the cases that include caps on CO_2 emissions, coal-fired generation in 2020 declines to about one-half the level expected without CO_2 emissions limits.

[31] Gasoline and diesel fuel with sulfur content below 10 parts per million.

future emissions. Approximately 80 percent of the nitrogen dioxide emissions in Australian cities come from motor vehicle exhaust [**15**].

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 will be 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 will apply starting in 2002, in order to ensure compatibility between the fuels and the vehicle emissions control technologies that will start to come into use at that time. The government plans to develop standards for other fuels over time.

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 were also established by the Air Pollution Control Law and by the Automobile NO_x Law of 1992.

Some developing countries have also enacted targeted air pollution abatement measures designed to limit energy-related emissions including sulfur dioxide and nitrogen oxide. Compliance with emissions regulations is often low in developing countries, however, particularly in the transportation sector, due to inadequate means for measuring emissions levels accurately and enforcing emissions standards [**16**]. Thus, in the face of strong population growth and economic development, emissions of criteria pollutants in urban centers of the developing world have increased steadily.

Urban air quality in India ranks among the world's poorest [**17**]. Efforts to improve urban air quality have focused significantly on vehicles, which account for the majority of the country's criteria pollutant emissions. 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 of 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 (out of a total fleet of 12,000), and protests ensued as all other buses were banned from use [**18**]. To ease the transition for both bus owners and commuters, the Delhi government is now allowing for a gradual phaseout of the existing diesel bus fleet [**19**].

Although India is a large coal consumer, the country's 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 natural gas and naphtha-based thermal plants face emissions standards between 50 parts per million and 100 parts per million, depending on their capacity. Enforcement of the standards has been recognized as a major problem in India [**20**].

References

1. Intergovernmental Panel on Climate Change, *Climate Change 2001: The Scientific Basis* (Cambridge, UK: Cambridge University Press, 2001).
2. United Nations, *United Nations Framework Convention on Climate Change: Article 2* (1992).
3. Commission of the European Communities, *Preparing for Implementation of the Kyoto Protocol*, Commission Communication to the Council and Parliament, COM (1999) 230 (May 19, 1999), web site www.europa.eu.int/comm/environment/docum/.

4. United Nations Framework Convention on Climate Change, "Greenhouse Gas Inventory Database," web site http://ghg.unfccc.int (not dated).
5. Commission of the European Communities, *Greenhouse Gas Emissions Trading Within the European Union*, Proposal for a Directive of the European Parliament and of the Council Establishing a Scheme for Greenhouse Gas Emission Allowance Trading Within the Community and Amending Council Directive 96/61/EC, COM (2001) 581 (October 23, 2001), web site www.europa.eu.int/comm/environment/docum/.
6. European Environment Agency, *Environmental Signals 2000: Environmental Assessment Report No. 6* (Copenhagen, Denmark, Office for Official Publication of the European Communities, 1999) web site http://reports.eea.eu.int/.
7. U.S. Environmental Protection Agency, *Final Emission Standards for 2004 and Later Model Year Highway Heavy Duty Vehicles and Engines*, EPA420-F-00-026 (Washington, DC, July 2000).
8. U.S. Environment Protection Agency, *Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements*, EPA420-f-00-057 (Washington, DC, December 2000).
9. 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*, 40 CFR Parts 80, 85, and 86 (February 10, 2000).
10. U.S. Environmental Protection Agency, "Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements: Final Rule," *Federal Register*, 40 CFR Parts 69, 80, and 86 (January 18, 2001).
11. Commission of the European Communities, *Proposal for a Directive Setting National Emission Ceilings for Certain Atmospheric Pollutants and for a Daughter Directive Related to Ozone in Ambient Air*, Proposal for a Directive of the European Parliament and of the Council on National Emission Ceilings for Certain Atmospheric Pollutants, COM (99) 125 (June 9, 1999), web site www.europa.eu.int comm/environment/docum/.
12. Council of the European Union, "Common Position (EC) No. 52/2000: Adopted by the Council on 9 November 2000," *Official Journal of the European Communities*, Vol. C375 (December 28, 2000), pp. 12-37, web site www.europa.eu.int/comm/environment/air/.
13. Commission of the European Communities, *The Clean Air for Europe (CAFE) Programme: Towards a Thematic Strategy for Air Quality*, Communication from the Commission, COM (2001) 245 (May 4, 2001), web site www.europa.eu.int/comm/environment/docum/.
14. "EU Advances Fuels Deadline," *The Oil Daily*, Vol. 51, No. 239 (December 13, 2001), p. 7.
15. Environment Australia, "Atmosphere: Air Quality: Major Pollutants: Fact Sheet on Nitrogen Dioxide" (November 12, 2001), web site www.ea.gov.au.
16. M. Kojima and M. Lovei, *Urban Air Quality Management: Coordinating Transport, Environment, and Energy Policies in Developing Countries*, Technical Paper No. 508 (Washington, DC: World Bank, September 2001), p. 17.
17. "Smoking Cities," BBC News Online (January 25, 1999), web site news.bbc.co.uk.
18. "Capital Punishment," *The Economist*, Vol. 359, No. 8216 (April 7, 2001), p. 44.
19. C. Chauhan, "Private Operators Told To Pull Out 3,700 Buses," *The Hindustani Times* (November 29, 2001).
20. S. Sinha, "Environmental Guidelines for Power Plants in India and Other Nations," *Environmental Quality Management*, Vol. 11, No. 1 (Autumn 2001), pp. 57-69.

Appendix A

Reference Case Projections:

World Energy Consumption
Gross Domestic Product
Carbon Dioxide Emissions
Nuclear Power Capacity
World Population

Table A1. World Total Energy Consumption by Region, Reference Case, 1990-2020
(Quadrillion Btu)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**100.1**	**112.7**	**115.7**	**129.3**	**140.5**	**151.3**	**161.3**	**1.6**
United States[a]	84.2	94.6	97.0	107.6	115.6	123.6	130.9	1.4
Canada	10.9	12.1	12.5	13.7	14.8	15.8	16.7	1.4
Mexico	5.0	6.1	6.1	7.9	10.0	11.9	13.7	3.9
Western Europe	**59.8**	**65.8**	**66.0**	**71.5**	**74.7**	**77.7**	**81.5**	**1.0**
United Kingdom	9.3	9.9	9.9	10.7	11.2	11.7	12.2	1.0
France	8.8	10.2	10.3	11.2	11.7	12.3	13.0	1.1
Germany	14.8	14.2	14.0	15.3	15.9	16.4	17.0	0.9
Italy	7.0	8.0	8.0	8.9	9.4	9.9	10.4	1.2
Netherlands	3.4	3.8	3.8	4.1	4.3	4.4	4.6	0.9
Other Western Europe	16.6	19.8	20.0	21.3	22.2	23.0	24.3	0.9
Industrialized Asia	**22.8**	**27.6**	**27.9**	**29.7**	**31.5**	**33.2**	**34.9**	**1.1**
Japan	17.9	21.5	21.7	22.9	24.2	25.4	26.6	1.0
Australasia	4.8	6.1	6.2	6.8	7.3	7.8	8.3	1.4
Total Industrialized	**182.7**	**206.1**	**209.7**	**230.6**	**246.6**	**262.2**	**277.8**	**1.3**
EE/FSU								
Former Soviet Union	60.7	38.7	39.2	44.1	48.0	53.1	57.1	1.8
Eastern Europe	15.6	11.9	11.2	12.7	13.8	15.2	16.3	1.8
Total EE/FSU	**76.3**	**50.6**	**50.4**	**56.8**	**61.8**	**68.2**	**73.4**	**1.8**
Developing Countries								
Developing Asia	**51.0**	**72.9**	**70.9**	**92.5**	**113.9**	**137.1**	**162.2**	**4.0**
China	27.0	35.3	31.9	42.9	55.1	68.8	84.4	4.7
India	7.8	11.6	12.2	15.2	18.2	21.8	25.4	3.6
South Korea	3.7	6.9	7.3	9.6	10.7	12.0	13.0	2.7
Other Asia	12.6	19.1	19.5	24.8	29.8	34.6	39.5	3.4
Middle East	**13.1**	**19.1**	**19.3**	**22.0**	**26.3**	**30.5**	**34.8**	**2.8**
Turkey	2.0	3.0	3.0	3.4	3.9	4.5	5.1	2.6
Other Middle East	11.1	16.1	16.4	18.7	22.4	26.0	29.7	2.9
Africa	**9.3**	**11.6**	**11.8**	**14.0**	**15.7**	**18.1**	**20.3**	**2.6**
Central and South America	**13.7**	**19.4**	**19.8**	**22.7**	**28.3**	**35.6**	**43.1**	**3.8**
Brazil	5.7	8.2	8.5	9.4	11.5	14.0	16.8	3.3
Other Central/South America	8.1	11.2	11.2	13.3	16.8	21.6	26.3	4.1
Total Developing	**87.2**	**123.0**	**121.8**	**151.2**	**184.1**	**221.3**	**260.3**	**3.7**
Total World	**346.2**	**379.7**	**381.9**	**438.6**	**492.6**	**551.7**	**611.5**	**2.3**
Annex I								
Industrialized	177.7	200.1	203.5	222.6	236.6	250.3	264.0	1.2
EE/FSU	64.6	43.4	43.3	48.5	52.5	57.8	61.9	1.7
Total Annex I	**242.3**	**243.5**	**246.9**	**271.2**	**289.1**	**308.1**	**326.0**	**1.3**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. 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 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table A1; and World Energy Projection System (2002).

Table A2. World Total Energy Consumption by Region and Fuel, Reference Case, 1990-2020
(Quadrillion Btu)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America								
Oil	40.4	44.6	45.8	50.6	56.0	61.2	66.2	1.8
Natural Gas	22.7	26.2	26.8	31.4	34.8	38.7	41.7	2.1
Coal	20.5	23.5	23.5	25.9	27.5	28.5	29.8	1.2
Nuclear	7.0	8.0	8.6	9.2	9.0	8.7	8.7	0.1
Other	9.5	10.7	11.4	12.1	13.1	14.1	14.8	1.3
Total	**100.1**	**112.7**	**115.7**	**129.3**	**140.5**	**151.3**	**161.3**	**1.6**
Western Europe								
Oil	25.8	29.1	28.7	30.7	31.4	32.0	32.5	0.6
Natural Gas	9.7	13.6	14.3	18.0	20.2	22.8	26.7	3.0
Coal	12.4	8.8	8.4	7.7	7.4	7.1	6.5	-1.2
Nuclear	7.4	8.8	8.9	8.6	8.6	8.2	7.5	-0.8
Other	4.5	5.4	5.6	6.5	7.1	7.6	8.2	1.9
Total	**59.8**	**65.8**	**66.0**	**71.5**	**74.7**	**77.7**	**81.5**	**1.0**
Industrialized Asia								
Oil	12.5	13.7	13.9	14.8	15.7	16.3	16.8	0.9
Natural Gas	2.5	3.6	3.8	4.1	4.3	4.8	5.5	1.9
Coal	4.2	5.3	5.4	5.8	6.0	6.2	6.3	0.7
Nuclear	2.0	3.2	3.2	3.3	3.6	3.8	4.1	1.2
Other	1.6	1.7	1.7	1.8	1.9	2.1	2.2	1.3
Total	**22.8**	**27.6**	**27.9**	**29.7**	**31.5**	**33.2**	**34.9**	**1.1**
Total Industrialized								
Oil	78.7	87.4	88.4	96.1	103.1	109.5	115.6	1.3
Natural Gas	35.0	43.5	44.8	53.5	59.4	66.3	74.0	2.4
Coal	37.1	37.5	37.3	39.4	41.0	41.8	42.7	0.6
Nuclear	16.3	20.0	20.6	21.1	21.1	20.8	20.3	-0.1
Other	15.6	17.9	18.6	20.4	22.1	23.8	25.3	1.5
Total	**182.7**	**206.1**	**209.7**	**230.6**	**246.6**	**262.2**	**277.8**	**1.3**
EE/FSU								
Oil	21.0	10.9	10.8	14.1	16.3	19.1	21.1	3.2
Natural Gas	28.8	22.7	22.9	25.2	28.6	32.8	37.0	2.3
Coal	20.8	11.4	11.1	11.2	10.5	9.6	8.6	-1.3
Nuclear	2.9	2.7	2.7	3.2	3.0	3.0	2.8	0.0
Other	2.8	3.0	3.0	3.2	3.4	3.7	4.1	1.5
Total	**76.3**	**50.6**	**50.4**	**56.8**	**61.8**	**68.2**	**73.4**	**1.8**
Developing Countries								
Developing Asia								
Oil	16.0	26.7	27.7	34.0	41.8	50.9	59.9	3.7
Natural Gas	3.2	6.0	6.4	10.8	14.1	18.3	22.8	6.2
Coal	27.7	34.5	30.7	39.0	47.0	54.7	64.0	3.6
Nuclear	0.9	1.5	1.6	2.3	2.9	3.5	4.4	4.8
Other	3.2	4.3	4.6	6.5	8.0	9.7	11.2	4.3
Total	**51.0**	**72.9**	**70.9**	**92.5**	**113.9**	**137.1**	**162.2**	**4.0**

See notes at end of table.

Table A2. World Total Energy Consumption by Region and Fuel, Reference Case, 1990-2020 (Continued)
(Quadrillion Btu)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Developing Countries (Continued)								
Middle East								
Oil	8.1	10.4	10.5	11.8	13.2	14.7	16.4	2.1
Natural Gas	3.9	6.9	7.1	8.3	10.8	13.0	15.3	3.7
Coal	0.8	1.2	1.1	1.2	1.4	1.5	1.5	1.3
Nuclear	0.0	0.0	0.0	0.0	0.1	0.1	0.1	—
Other	0.4	0.6	0.5	0.8	0.9	1.2	1.5	5.2
Total	**13.1**	**19.1**	**19.3**	**22.0**	**26.3**	**30.5**	**34.8**	**2.8**
Africa								
Oil	4.2	5.1	5.2	6.7	8.0	9.4	10.9	3.6
Natural Gas	1.5	2.0	2.1	2.5	2.8	3.3	3.8	2.7
Coal	3.0	3.7	3.6	3.8	3.9	4.2	4.3	0.9
Nuclear	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.9
Other	0.6	0.7	0.7	0.8	0.9	1.0	1.2	2.5
Total	**9.3**	**11.6**	**11.8**	**14.0**	**15.7**	**18.1**	**20.3**	**2.6**
Central and South America								
Oil	7.0	9.4	9.5	10.6	13.0	15.3	18.1	3.1
Natural Gas	2.2	3.4	3.5	4.9	7.7	12.0	15.9	7.4
Coal	0.6	0.9	0.9	1.0	1.0	1.1	1.3	1.7
Nuclear	0.1	0.1	0.1	0.2	0.2	0.2	0.2	3.7
Other	3.9	5.6	5.7	6.0	6.4	7.0	7.6	1.4
Total	**13.7**	**19.4**	**19.8**	**22.7**	**28.3**	**35.6**	**43.1**	**3.8**
Total Developing Countries								
Oil	35.2	51.5	52.9	63.1	76.0	90.3	105.2	3.3
Natural Gas	10.8	18.3	19.2	26.4	35.4	46.7	57.7	5.4
Coal	32.1	40.3	36.3	44.9	53.3	61.5	71.1	3.3
Nuclear	1.1	1.7	1.9	2.6	3.3	3.9	4.9	4.7
Other	8.0	11.1	11.5	14.1	16.1	18.9	21.4	3.0
Total	**87.2**	**123.0**	**121.8**	**151.2**	**184.1**	**221.3**	**260.3**	**3.7**
Total World								
Oil	134.9	149.8	152.2	173.4	195.4	219.0	241.8	2.2
Natural Gas	74.5	84.5	86.9	105.2	123.4	145.8	168.6	3.2
Coal	90.0	89.3	84.8	95.6	104.7	112.8	122.3	1.8
Nuclear	20.4	24.4	25.3	26.9	27.5	27.7	28.0	0.5
Other	26.5	32.0	33.1	37.6	41.6	46.4	50.7	2.1
Total	**346.2**	**379.7**	**381.9**	**438.6**	**492.6**	**551.7**	**611.5**	**2.3**

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 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table A1; and World Energy Projection System (2002).

Table A3. World Gross Domestic Product (GDP) by Region, Reference Case, 1990-2020
(Billion 1997 Dollars)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**7,723**	**9,760**	**10,165**	**12,014**	**14,280**	**16,770**	**19,349**	**3.1**
United States[a]	6,836	8,675	9,029	10,620	12,559	14,676	16,837	3.0
Canada	555	665	699	829	967	1,110	1,262	2.9
Mexico	332	421	437	565	754	985	1,249	5.1
Western Europe	**7,597**	**8,731**	**8,944**	**10,381**	**11,723**	**13,181**	**14,786**	**2.4**
United Kingdom	1,146	1,353	1,384	1,613	1,839	2,085	2,357	2.6
France	1,299	1,455	1,499	1,744	1,965	2,200	2,443	2.4
Germany	1,879	2,156	2,187	2,506	2,801	3,123	3,481	2.2
Italy	1,079	1,188	1,207	1,380	1,565	1,767	2,006	2.4
Netherlands	317	392	407	475	535	601	673	2.4
Other Western Europe	1,877	2,187	2,260	2,665	3,017	3,405	3,826	2.5
Industrialized Asia	**4,054**	**4,765**	**4,821**	**5,140**	**5,860**	**6,629**	**7,474**	**2.1**
Japan	3,673	4,271	4,304	4,530	5,155	5,818	6,545	2.0
Australasia	381	494	516	611	705	812	929	2.8
Total Industrialized	**19,374**	**23,256**	**23,930**	**27,536**	**31,863**	**36,580**	**41,609**	**2.7**
EE/FSU								
Former Soviet Union	1,009	545	569	761	948	1,236	1,501	4.7
Eastern Europe	348	358	363	459	568	693	837	4.1
Total EE/FSU	**1,357**	**903**	**932**	**1,221**	**1,516**	**1,929**	**2,337**	**4.5**
Developing Countries								
Developing Asia	**1,739**	**2,975**	**3,165**	**4,355**	**5,823**	**7,538**	**9,690**	**5.5**
China	427	968	1,037	1,588	2,287	3,146	4,315	7.0
India	268	445	473	653	865	1,145	1,507	5.7
South Korea	297	445	493	674	861	1,044	1,232	4.5
Other Asia	748	1,118	1,162	1,440	1,810	2,202	2,636	4.0
Middle East	**379**	**580**	**577**	**722**	**900**	**1,115**	**1,363**	**4.2**
Turkey	140	196	186	224	278	342	416	3.9
Other Middle East	239	384	391	498	622	773	947	4.3
Africa	**405**	**485**	**499**	**628**	**768**	**929**	**1,110**	**3.9**
Central and South America	**1,136**	**1,467**	**1,452**	**1,715**	**2,191**	**2,815**	**3,623**	**4.5**
Brazil	674	810	816	1,002	1,302	1,711	2,258	5.0
Other Central/South America	462	657	636	713	890	1,104	1,365	3.7
Total Developing	**3,660**	**5,507**	**5,693**	**7,420**	**9,683**	**12,397**	**15,786**	**5.0**
Total World	**24,392**	**29,665**	**30,555**	**36,176**	**43,063**	**50,906**	**59,733**	**3.2**
Annex I								
Industrialized	19,043	22,835	23,493	26,970	31,109	35,596	40,360	2.6
EE/FSU	1,212	813	842	1,096	1,353	1,720	2,076	4.4
Total Annex I	**20,255**	**23,648**	**24,335**	**28,067**	**32,462**	**37,316**	**42,436**	**2.7**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.
Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding.
Sources: DRI-WEFA, *World Economic Outlook*, Vol. 1 (Lexington, MA, 3rd Quarter 2001); and Energy Information Administration, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table A20.

Table A4. World Oil Consumption by Region, Reference Case, 1990-2020
(Million Barrels per Day)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**20.4**	**22.7**	**23.4**	**25.9**	**28.6**	**31.2**	**33.7**	**1.8**
United States[a]	17.0	18.9	19.5	21.3	23.2	25.1	26.7	1.5
Canada	1.7	1.9	1.9	2.1	2.2	2.3	2.4	1.1
Mexico	1.7	1.9	2.0	2.5	3.1	3.8	4.6	4.1
Western Europe	**12.5**	**14.1**	**13.9**	**14.9**	**15.2**	**15.5**	**15.8**	**0.6**
United Kingdom	1.8	1.8	1.7	2.0	2.1	2.2	2.2	1.2
France	1.8	2.0	2.0	2.1	2.2	2.3	2.3	0.6
Germany	2.7	2.9	2.8	3.1	3.1	3.2	3.2	0.6
Italy	1.9	2.1	2.0	2.1	2.1	2.2	2.2	0.5
Netherlands	0.7	0.8	0.8	0.9	0.9	0.9	1.0	0.7
Other Western Europe	3.6	4.5	4.5	4.7	4.8	4.8	4.9	0.4
Industrialized Asia	**6.2**	**6.8**	**6.9**	**7.3**	**7.8**	**8.0**	**8.3**	**0.9**
Japan	5.1	5.5	5.6	5.9	6.2	6.3	6.4	0.7
Australasia	1.0	1.3	1.3	1.5	1.6	1.7	1.9	1.8
Total Industrialized	**39.0**	**43.6**	**44.2**	**48.1**	**51.5**	**54.8**	**57.8**	**1.3**
EE/FSU								
Former Soviet Union	8.4	3.8	3.7	5.0	5.9	7.1	8.0	3.7
Eastern Europe	1.6	1.4	1.5	1.7	1.9	2.0	2.1	1.8
Total EE/FSU	**10.0**	**5.2**	**5.2**	**6.7**	**7.8**	**9.2**	**10.1**	**3.2**
Developing Countries								
Developing Asia	**7.6**	**12.8**	**13.3**	**16.3**	**20.1**	**24.5**	**28.8**	**3.7**
China	2.3	4.1	4.3	5.3	6.8	8.6	10.5	4.3
India	1.2	1.8	1.9	2.5	3.2	4.1	4.9	4.6
South Korea	1.0	2.0	2.0	2.5	2.8	2.9	3.0	1.9
Other Asia	3.1	4.9	5.0	6.1	7.4	8.8	10.3	3.5
Middle East	**3.9**	**5.0**	**5.0**	**5.7**	**6.3**	**7.0**	**7.8**	**2.1**
Turkey	0.5	0.6	0.6	0.8	0.9	1.0	1.2	3.0
Other Middle East	3.4	4.3	4.4	4.9	5.4	6.0	6.7	2.0
Africa	**2.1**	**2.5**	**2.5**	**3.3**	**3.9**	**4.5**	**5.3**	**3.6**
Central and South America	**3.4**	**4.6**	**4.7**	**5.2**	**6.3**	**7.5**	**8.8**	**3.1**
Brazil	1.3	1.9	2.0	2.1	2.5	3.1	3.9	3.3
Other Central/South America	2.1	2.7	2.7	3.1	3.8	4.3	4.9	2.9
Total Developing	**17.0**	**24.8**	**25.5**	**30.4**	**36.6**	**43.5**	**50.7**	**3.3**
Total World	**66.0**	**73.6**	**74.9**	**85.2**	**96.0**	**107.5**	**118.6**	**2.2**
Annex I								
Industrialized	37.3	41.7	42.2	45.5	48.4	50.9	53.1	1.1
EE/FSU	8.1	4.3	4.2	5.5	6.4	7.4	8.2	3.2
Total Annex I	**45.4**	**45.9**	**46.5**	**51.0**	**54.8**	**58.4**	**61.3**	**1.3**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. 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 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table A21; and World Energy Projection System (2002).

Table A5. World Natural Gas Consumption by Region, Reference Case, 1990-2020
(Trillion Cubic Feet)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**22.0**	**25.4**	**26.1**	**30.6**	**33.9**	**37.7**	**40.7**	**2.1**
United States[a]	18.7	21.3	21.7	25.5	28.1	31.3	33.8	2.1
Canada	2.4	2.9	3.1	3.3	3.6	3.9	4.3	1.6
Mexico	0.9	1.3	1.3	1.8	2.2	2.5	2.6	3.4
Western Europe	**10.1**	**13.4**	**14.0**	**17.6**	**19.7**	**22.2**	**25.9**	**3.0**
United Kingdom	2.1	3.1	3.3	3.7	4.2	4.8	5.5	2.5
France	1.0	1.3	1.3	1.8	2.1	2.4	2.9	3.7
Germany	2.7	3.0	3.0	4.0	4.4	4.8	5.8	3.2
Italy	1.7	2.2	2.4	2.9	3.3	3.6	4.0	2.5
Netherlands	1.5	1.8	1.7	1.9	2.1	2.2	2.3	1.4
Other Western Europe	1.2	2.0	2.3	3.2	3.6	4.4	5.4	4.2
Industrialized Asia	**2.6**	**3.5**	**3.6**	**4.0**	**4.2**	**4.6**	**5.3**	**1.9**
Japan	1.9	2.5	2.6	2.8	2.9	3.2	3.8	1.7
Australasia	0.8	0.9	1.0	1.1	1.3	1.4	1.6	2.3
Total Industrialized	**34.8**	**42.3**	**43.7**	**52.1**	**57.8**	**64.5**	**71.9**	**2.4**
EE/FSU								
Former Soviet Union	25.0	19.9	20.1	21.7	24.0	27.0	30.1	1.9
Eastern Europe	3.1	2.5	2.4	3.1	4.1	5.3	6.3	4.7
Total EE/FSU	**28.1**	**22.4**	**22.5**	**24.8**	**28.1**	**32.3**	**36.4**	**2.3**
Developing Countries								
Developing Asia	**3.0**	**5.6**	**6.0**	**10.1**	**13.1**	**16.9**	**20.9**	**6.1**
China	0.5	0.8	0.9	1.8	2.8	4.5	6.4	10.1
India	0.4	0.8	0.8	1.2	1.6	2.2	2.6	6.1
South Korea	0.1	0.5	0.6	1.2	1.4	1.8	2.3	6.6
Other Asia	1.9	3.6	3.8	5.9	7.3	8.3	9.6	4.5
Middle East	**3.7**	**6.6**	**6.8**	**7.9**	**10.3**	**12.4**	**14.6**	**3.7**
Turkey	0.1	0.4	0.4	0.5	0.6	0.8	1.1	4.2
Other Middle East	3.6	6.2	6.3	7.4	9.7	11.6	13.5	3.7
Africa	**1.4**	**1.8**	**2.0**	**2.3**	**2.5**	**3.1**	**3.5**	**7.4**
Central and South America	**2.0**	**3.1**	**3.2**	**4.5**	**7.1**	**11.1**	**14.6**	**7.4**
Brazil	0.1	0.2	0.2	0.6	1.3	2.4	3.2	13.3
Other Central/South America	1.9	2.9	3.0	3.9	5.8	8.7	11.4	6.5
Total Developing	**10.1**	**17.2**	**18.0**	**24.7**	**33.1**	**43.4**	**53.5**	**5.3**
Total World	**72.9**	**81.9**	**84.2**	**101.7**	**119.0**	**140.2**	**161.8**	**3.2**
Annex I								
Industrialized	33.9	41.0	42.4	50.4	55.6	62.1	69.3	2.4
EE/FSU	24.2	19.3	19.3	20.9	23.5	27.1	30.5	2.2
Total Annex I	**58.1**	**60.2**	**61.7**	**71.3**	**79.1**	**89.2**	**99.9**	**2.3**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. 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 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table A13; and World Energy Projection System (2002).

Table A6. World Coal Consumption by Region, Reference Case, 1990-2020
(Million Short Tons)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**959**	**1,121**	**1,122**	**1,263**	**1,349**	**1,401**	**1,480**	**1.3**
United States[a]	895	1,040	1,045	1,176	1,251	1,294	1,365	1.3
Canada	55	66	63	66	73	78	83	1.3
Mexico	9	15	13	21	25	29	32	4.3
Western Europe	**894**	**566**	**546**	**498**	**485**	**469**	**436**	**-1.1**
United Kingdom	119	70	65	60	58	53	43	-1.9
France	35	29	26	23	16	17	14	-3.1
Germany	528	269	258	237	237	233	219	-0.8
Italy	23	19	19	17	17	15	15	-1.2
Netherlands	15	16	14	12	8	8	7	-3.3
Other Western Europe	173	164	165	149	148	143	138	-0.8
Industrialized Asia	**231**	**287**	**295**	**311**	**323**	**332**	**337**	**0.6**
Japan	125	144	149	164	173	181	185	1.0
Australasia	106	142	145	148	149	151	152	0.2
Total Industrialized	**2,084**	**1,974**	**1,963**	**2,072**	**2,157**	**2,201**	**2,252**	**0.7**
EE/FSU								
Former Soviet Union	848	396	414	421	397	364	326	-1.1
Eastern Europe	527	414	363	361	330	298	263	-1.5
Total EE/FSU	**1,375**	**810**	**778**	**782**	**727**	**662**	**589**	**-1.3**
Developing Countries								
Developing Asia	**1,583**	**1,903**	**1,686**	**2,141**	**2,577**	**3,004**	**3,515**	**3.6**
China	1,124	1,300	1,075	1,421	1,797	2,170	2,592	4.3
India	242	333	348	414	450	482	546	2.2
South Korea	42	60	65	81	89	94	96	1.8
Other Asia	175	210	197	226	241	258	282	1.7
Middle East	**66**	**99**	**96**	**101**	**119**	**125**	**127**	**1.3**
Turkey	60	86	84	88	98	102	104	1.0
Other Middle East	6	12	12	12	21	23	23	3.1
Africa	**152**	**181**	**177**	**186**	**191**	**203**	**212**	**0.9**
Central and South America	**26**	**42**	**41**	**43**	**47**	**52**	**58**	**1.7**
Brazil	17	28	27	30	35	40	47	2.6
Other Central/South America	9	15	14	14	12	12	11	-0.9
Total Developing	**1,827**	**2,226**	**2,000**	**2,472**	**2,935**	**3,384**	**3,912**	**3.2**
Total World	**5,287**	**5,009**	**4,740**	**5,326**	**5,819**	**6,247**	**6,753**	**1.7**
Annex I								
Industrialized	2,075	1,959	1,950	2,051	2,132	2,172	2,220	0.6
EE/FSU	1,166	702	686	692	650	594	535	-1.2
Total Annex I	**3,242**	**2,660**	**2,635**	**2,743**	**2,781**	**2,766**	**2,755**	**0.2**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country. 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 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table A16; and World Energy Projection System (2002).

Table A7. World Nuclear Energy Consumption by Region, Reference Case, 1990-2020
(Billion Kilowatthours)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**649**	**750**	**808**	**860**	**841**	**814**	**811**	**0.0**
United States[a]	577	674	728	759	737	707	702	-0.2
Canada	69	68	70	92	95	97	100	1.7
Mexico	3	9	10	9	9	9	9	-0.2
Western Europe	**703**	**836**	**846**	**830**	**821**	**790**	**728**	**-0.7**
United Kingdom	59	95	91	67	60	52	31	-5.0
France	298	369	375	393	400	406	423	0.6
Germany	145	154	161	154	147	138	104	-2.1
Italy	0	0	0	0	0	0	0	—
Netherlands	3	4	4	4	0	0	0	-100.0
Other Western Europe	198	215	215	212	215	193	170	-1.1
Industrialized Asia	**192**	**316**	**309**	**318**	**347**	**374**	**398**	**1.2**
Japan	192	316	309	318	347	374	398	1.2
Australasia	0	0	0	0	0	0	0	—
Total Industrialized	**1,544**	**1,902**	**1,962**	**2,008**	**2,010**	**1,977**	**1,937**	**-0.1**
EE/FSU								
Former Soviet Union	201	183	190	207	203	202	171	-0.5
Eastern Europe	54	61	60	82	73	74	81	1.4
Total EE/FSU	**256**	**244**	**250**	**288**	**276**	**276**	**252**	**0.0**
Developing Countries								
Developing Asia	**88**	**145**	**160**	**231**	**289**	**342**	**425**	**11.2**
China	0	13	14	51	75	91	131	11.2
India	6	11	11	15	25	30	45	6.8
South Korea	50	85	98	126	130	157	180	2.9
Other Asia	32	36	37	38	58	64	69	3.0
Middle East	**0**	**0**	**0**	**0**	**6**	**12**	**13**	**—**
Turkey	0	0	0	0	0	0	0	—
Other Middle East	0	0	0	0	6	12	13	—
Africa	**8**	**14**	**13**	**12**	**13**	**14**	**15**	**0.9**
Central and South America	**9**	**10**	**11**	**17**	**17**	**16**	**24**	**4.1**
Brazil	2	3	4	10	11	12	20	8.3
Other Central/South America	7	7	7	6	6	4	4	-2.2
Total Developing	**105**	**169**	**184**	**260**	**325**	**384**	**478**	**4.7**
Total World	**1,905**	**2,315**	**2,396**	**2,555**	**2,610**	**2,637**	**2,667**	**0.5**
Annex I								
Industrialized	1,541	1,893	1,952	1,999	2,000	1,968	1,928	-0.1
EE/FSU	255	243	248	286	276	276	252	0.1
Total Annex I	**1,797**	**2,136**	**2,200**	**2,285**	**2,277**	**2,244**	**2,179**	**0.0**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table A8; and World Energy Projection System (2002).

Table A8. World Consumption of Hydroelectricity and Other Renewable Energy by Region, Reference Case, 1990-2020
(Quadrillion Btu)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**9.5**	**10.7**	**11.4**	**12.1**	**13.1**	**14.1**	**14.8**	**1.3**
United States[a]	6.1	6.9	7.3	7.9	8.3	8.9	9.4	1.2
Canada	3.1	3.5	3.6	3.6	4.0	4.3	4.5	1.1
Mexico	0.3	0.4	0.4	0.5	0.8	0.9	0.9	3.5
Western Europe	**4.5**	**5.4**	**5.6**	**6.5**	**7.1**	**7.6**	**8.2**	**1.9**
United Kingdom	0.1	0.1	0.1	0.3	0.3	0.4	0.4	5.6
France	0.6	0.7	0.8	0.2	0.3	0.3	0.4	-3.5
Germany	0.3	0.3	0.4	0.6	0.7	0.8	1.0	4.8
Italy	0.4	0.5	0.6	1.1	1.2	1.3	1.4	4.3
Netherlands	0.0	0.0	0.0	0.3	0.3	0.3	0.4	10.4
Other Western Europe	3.2	3.7	3.7	4.0	4.1	4.3	4.7	1.1
Industrialized Asia	**1.6**	**1.7**	**1.7**	**1.8**	**1.9**	**2.1**	**2.2**	**1.3**
Japan	1.1	1.2	1.2	1.2	1.3	1.4	1.5	1.3
Australasia	0.4	0.5	0.5	0.6	0.6	0.6	0.7	1.4
Total Industrialized	**15.6**	**17.9**	**18.6**	**20.4**	**22.1**	**23.8**	**25.3**	**1.5**
EE/FSU								
Former Soviet Union	2.4	2.3	2.3	2.5	2.6	2.7	2.8	0.8
Eastern Europe	0.4	0.6	0.6	0.7	0.9	1.1	1.3	3.4
Total EE/FSU	**2.8**	**3.0**	**3.0**	**3.2**	**3.4**	**3.7**	**4.1**	**1.5**
Developing Countries								
Developing Asia	**3.2**	**4.3**	**4.6**	**6.5**	**8.0**	**9.7**	**11.2**	**4.3**
China	1.3	2.1	2.3	3.4	4.3	5.4	6.6	5.1
India	0.7	0.8	0.9	1.1	1.3	1.5	1.7	3.3
South Korea	0.0	0.0	0.0	0.1	0.1	0.2	0.2	7.9
Other Asia	1.1	1.3	1.4	1.9	2.3	2.6	2.7	3.2
Middle East	**0.4**	**0.6**	**0.5**	**0.8**	**0.9**	**1.2**	**1.5**	**5.2**
Turkey	0.2	0.4	0.4	0.4	0.5	0.5	0.5	2.0
Other Middle East	0.1	0.2	0.2	0.4	0.4	0.7	1.0	8.8
Africa	**0.6**	**0.7**	**0.7**	**0.8**	**0.9**	**1.0**	**1.2**	**2.5**
Central and South America	**3.9**	**5.6**	**5.7**	**6.0**	**6.4**	**7.0**	**7.6**	**1.4**
Brazil	2.2	3.1	3.3	3.8	4.1	4.2	4.4	1.4
Other Central/South America	1.7	2.5	2.4	2.2	2.3	2.8	3.2	1.4
Total Developing	**8.0**	**11.1**	**11.5**	**14.1**	**16.1**	**18.9**	**21.4**	**3.0**
Total World	**26.5**	**32.0**	**33.1**	**37.6**	**41.6**	**46.4**	**50.7**	**2.1**
Annex I								
Industrialized	15.3	17.5	18.2	19.8	21.3	22.9	24.3	1.4
EE/FSU	2.2	2.3	2.3	2.4	2.6	2.8	3.1	1.5
Total Annex I	**17.4**	**19.8**	**20.5**	**22.2**	**23.8**	**25.7**	**27.4**	**1.4**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country. U.S. totals include net electricity imports, methanol, and liquid hydrogen.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table A1; and World Energy Projection System (2002).

Table A9. World Net Electricity Consumption by Region, Reference Case, 1990-2020
(Billion Kilowatthours)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**3,362**	**4,046**	**3,904**	**4,585**	**5,093**	**5,605**	**6,100**	**2.1**
United States[a]	2,817	3,400	3,236	3,793	4,170	4,556	4,916	2.0
Canada	438	485	498	558	612	661	711	1.7
Mexico	107	162	171	235	311	388	473	5.0
Western Europe	**2,077**	**2,399**	**2,435**	**2,743**	**2,959**	**3,183**	**3,455**	**1.7**
United Kingdom	287	330	333	365	389	413	438	1.3
France	326	394	399	450	486	523	572	1.7
Germany	489	492	495	567	609	649	699	1.7
Italy	222	266	272	320	356	395	438	2.3
Netherlands	72	95	98	110	118	128	138	1.7
Other Western Europe	681	822	838	931	999	1,074	1,170	1.6
Industrialized Asia	**945**	**1,158**	**1,178**	**1,292**	**1,395**	**1,493**	**1,596**	**1.5**
Japan	765	932	947	1,036	1,117	1,194	1,275	1.4
Australasia	181	226	231	255	278	299	322	1.6
Total Industrialized	**6,385**	**7,604**	**7,517**	**8,620**	**9,446**	**10,281**	**11,151**	**1.9**
EE/FSU								
Former Soviet Union	1,488	1,068	1,075	1,218	1,331	1,479	1,600	1.9
Eastern Europe	418	390	377	433	475	527	573	2.0
Total EE/FSU	**1,906**	**1,459**	**1,452**	**1,651**	**1,807**	**2,006**	**2,173**	**1.9**
Developing Countries								
Developing Asia	**1,259**	**2,175**	**2,319**	**3,092**	**3,900**	**4,819**	**5,858**	**4.5**
China	551	1,013	1,084	1,523	2,031	2,631	3,349	5.5
India	257	396	424	537	649	784	923	3.8
South Korea	93	207	233	309	348	392	429	3.0
Other Asia	357	560	578	724	872	1,012	1,157	3.4
Middle East	**263**	**470**	**494**	**572**	**690**	**808**	**932**	**3.1**
Turkey	51	102	106	122	144	166	190	2.8
Other Middle East	213	368	388	449	546	642	742	3.1
Africa	**287**	**361**	**367**	**460**	**550**	**671**	**776**	**3.6**
Central and South America	**449**	**656**	**684**	**788**	**988**	**1,249**	**1,517**	**3.9**
Brazil	229	334	354	398	494	613	748	3.6
Other Central/South America	220	322	330	390	494	635	769	4.1
Total Developing	**2,258**	**3,663**	**3,863**	**4,912**	**6,127**	**7,548**	**9,082**	**4.2**
Total World	**10,549**	**12,725**	**12,833**	**15,182**	**17,380**	**19,835**	**22,407**	**2.7**
Annex I								
Industrialized	6,278	7,442	7,346	8,385	9,135	9,893	10,678	1.8
EE/FSU	1,576	1,227	1,268	1,388	1,519	1,687	1,828	1.8
Total Annex I	**7,854**	**8,669**	**8,615**	**9,773**	**10,654**	**11,580**	**12,506**	**1.8**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Electricity consumption equals generation plus imports minus exports minus distribution losses.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table A2; and World Energy Projection System (2002).

Table A10. World Carbon Dioxide Emissions by Region, Reference Case, 1990-2020
(Million Metric Tons Carbon Equivalent)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**1,562**	**1,742**	**1,767**	**1,986**	**2,171**	**2,346**	**2,515**	**1.7**
United States[a]	1,352	1,495	1,517	1,694	1,835	1,965	2,088	1.5
Canada	126	146	150	160	173	185	196	1.3
Mexico	84	101	101	132	164	197	231	4.0
Western Europe	**930**	**947**	**940**	**1,008**	**1,045**	**1,086**	**1,136**	**0.9**
United Kingdom	164	154	151	167	176	183	191	1.1
France	102	110	109	118	122	128	136	1.1
Germany	271	237	230	246	253	259	270	0.8
Italy	112	122	121	132	139	144	150	1.0
Netherlands	58	66	64	67	67	70	71	0.5
Other Western Europe	223	260	264	278	288	301	318	0.9
Industrialized Asia	**357**	**412**	**422**	**451**	**475**	**496**	**518**	**1.0**
Japan	269	300	307	327	343	356	370	0.9
Australasia	88	112	115	124	132	140	148	1.2
Total Industrialized	**2,849**	**3,101**	**3,129**	**3,445**	**3,692**	**3,928**	**4,169**	**1.4**
EE/FSU								
Former Soviet Union	1,036	599	607	685	745	822	884	1.8
Eastern Europe	301	217	203	222	233	246	255	1.1
Total EE/FSU	**1,337**	**816**	**810**	**907**	**978**	**1,068**	**1,139**	**1.6**
Developing Countries								
Developing Asia	**1,053**	**1,435**	**1,361**	**1,748**	**2,139**	**2,558**	**3,017**	**3.9**
China	617	765	669	881	1,127	1,393	1,692	4.5
India	153	231	242	298	349	410	475	3.3
South Korea	61	101	107	136	152	164	175	2.3
Other Asia	223	338	343	433	511	591	675	3.3
Middle East	**231**	**325**	**330**	**372**	**439**	**501**	**566**	**2.6**
Turkey	35	50	50	57	64	71	80	2.2
Other Middle East	196	275	280	315	375	430	486	2.7
Africa	**179**	**216**	**218**	**256**	**287**	**327**	**365**	**2.5**
Central and South America	**178**	**246**	**249**	**290**	**377**	**484**	**595**	**4.2**
Brazil	62	87	88	100	130	169	213	4.3
Other Central/South America	116	159	162	190	247	315	382	4.2
Total Developing	**1,641**	**2,222**	**2,158**	**2,667**	**3,241**	**3,870**	**4,542**	**3.6**
Total World	**5,827**	**6,139**	**6,097**	**7,018**	**7,910**	**8,866**	**9,850**	**2.3**
Annex I								
Industrialized	2,765	3,001	3,028	3,313	3,527	3,731	3,938	1.3
EE/FSU	1,132	704	700	776	832	905	962	1.5
Total Annex I	**3,897**	**3,704**	**3,729**	**4,088**	**4,359**	**4,636**	**4,900**	**1.3**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. The U.S. numbers include carbon dioxide emissions attributable to renewable energy sources.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table A19; and World Energy Projection System (2002).

Table A11. World Carbon Dioxide Emissions from Oil Use by Region, Reference Case, 1990-2020
(Million Metric Tons Carbon Equivalent)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**716**	**775**	**793**	**874**	**969**	**1,064**	**1,154**	**1.8**
United States[a]	590	635	650	705	771	835	891	1.5
Canada	61	66	68	73	78	82	85	1.1
Mexico	65	74	76	96	120	146	177	4.1
Western Europe	**474**	**525**	**517**	**552**	**566**	**576**	**586**	**0.6**
United Kingdom	66	65	63	74	76	79	81	1.2
France	67	72	72	76	79	81	82	0.6
Germany	103	107	104	113	115	116	117	0.6
Italy	74	78	74	80	81	81	82	0.5
Netherlands	27	30	31	32	34	35	36	0.7
Other Western Europe	138	172	173	178	182	185	187	0.4
Industrialized Asia	**217**	**230**	**233**	**248**	**263**	**273**	**282**	**0.9**
Japan	179	183	185	195	205	209	213	0.7
Australasia	38	46	48	53	58	63	69	1.8
Total Industrialized	**1,407**	**1,529**	**1,543**	**1,675**	**1,798**	**1,912**	**2,021**	**1.3**
EE/FSU								
Former Soviet Union	334	148	146	197	233	280	312	3.7
Eastern Europe	66	55	55	64	70	76	80	1.8
Total EE/FSU	**400**	**202**	**201**	**261**	**303**	**355**	**392**	**3.2**
Developing Countries								
Developing Asia	**304**	**479**	**496**	**609**	**750**	**914**	**1,074**	**3.7**
China	94	152	160	196	251	317	390	4.3
India	45	70	73	94	121	158	187	4.6
South Korea	38	60	62	76	85	90	93	1.9
Other Asia	127	197	201	243	294	349	404	3.4
Middle East	**155**	**195**	**198**	**222**	**248**	**277**	**308**	**2.1**
Turkey	17	22	22	27	31	36	40	3.0
Other Middle East	138	173	177	195	216	241	267	2.0
Africa	**83**	**95**	**97**	**126**	**150**	**175**	**203**	**3.6**
Central and South America	**132**	**173**	**176**	**197**	**239**	**283**	**335**	**3.1**
Brazil	51	70	71	77	93	114	141	3.3
Other Central/South America	81	104	105	120	147	169	193	2.9
Total Developing	**674**	**942**	**968**	**1,154**	**1,387**	**1,648**	**1,919**	**3.3**
Total World	**2,482**	**2,673**	**2,712**	**3,090**	**3,488**	**3,916**	**4,332**	**2.3**
Annex I								
Industrialized	1,342	1,455	1,468	1,578	1,679	1,766	1,844	1.1
EE/FSU	324	164	162	211	244	286	314	3.2
Total Annex I	**1,666**	**1,620**	**1,630**	**1,790**	**1,923**	**2,052**	**2,158**	**1.3**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table A19; and World Energy Projection System (2002).

Table A12. World Carbon Dioxide Emissions from Natural Gas Use by Region, Reference Case, 1990-2020
(Million Metric Tons Carbon Equivalent)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**326**	**377**	**381**	**450**	**499**	**555**	**598**	**2.2**
United States[a]	277	315	317	374	413	460	496	2.2
Canada	35	42	46	49	53	58	63	1.6
Mexico	15	20	19	26	33	37	39	3.4
Western Europe	**140**	**196**	**206**	**259**	**291**	**328**	**385**	**3.0**
United Kingdom	30	47	50	57	65	73	84	2.5
France	16	21	21	29	34	38	46	3.2
Germany	32	42	43	57	62	68	82	3.2
Italy	25	32	35	42	48	54	59	2.5
Netherlands	20	23	22	25	27	28	30	1.4
Other Western Europe	18	31	35	50	56	68	84	4.2
Industrialized Asia	**36**	**52**	**54**	**59**	**62**	**69**	**80**	**1.9**
Japan	24	38	40	43	43	48	56	1.7
Australasia	12	14	14	17	19	21	23	2.3
Total Industrialized	**503**	**626**	**641**	**768**	**852**	**953**	**1,062**	**2.4**
EE/FSU								
Former Soviet Union	369	291	294	317	351	394	440	1.9
Eastern Europe	46	36	35	46	60	78	93	4.7
Total EE/FSU	**414**	**327**	**329**	**363**	**411**	**472**	**532**	**2.3**
Developing Countries								
Developing Asia	**45**	**86**	**92**	**155**	**204**	**263**	**328**	**6.2**
China	8	13	14	31	47	76	108	10.1
India	7	13	12	19	26	36	43	6.1
South Korea	2	8	10	15	19	23	30	5.5
Other Asia	29	53	56	90	111	129	147	4.7
Middle East	**56**	**100**	**102**	**120**	**156**	**187**	**220**	**3.7**
Turkey	2	6	7	7	7	10	13	3.0
Other Middle East	54	94	96	113	148	177	207	3.7
Africa	**22**	**29**	**31**	**36**	**40**	**48**	**54**	**2.7**
Central and South America	**32**	**49**	**51**	**70**	**111**	**173**	**228**	**7.4**
Brazil	2	3	4	8	20	35	48	13.3
Other Central/South America	30	46	47	62	92	138	180	6.6
Total Developing	**155**	**263**	**276**	**380**	**510**	**672**	**831**	**5.4**
Total World	**1,072**	**1,216**	**1,247**	**1,512**	**1,774**	**2,096**	**2,425**	**3.2**
Annex I								
Industrialized	488	606	622	742	819	916	1,023	2.4
EE/FSU	344	296	277	281	284	305	343	1.0
Total Annex I	**832**	**902**	**900**	**1,023**	**1,103**	**1,220**	**1,367**	**2.0**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.
Notes: EE/FSU = Eastern Europe/Former Soviet Union.
Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table A19; and World Energy Projection System (2002).

Table A13. World Carbon Dioxide Emissions from Coal Use by Region, Reference Case, 1990-2020
(Million Metric Tons Carbon Equivalent)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**520**	**595**	**592**	**662**	**704**	**728**	**763**	**1.2**
United States[a]	485	550	549	614	650	670	701	1.2
Canada	31	38	36	38	42	45	47	1.3
Mexico	4	7	6	10	12	13	15	4.4
Western Europe	**315**	**225**	**216**	**196**	**188**	**181**	**166**	**-1.3**
United Kingdom	68	42	39	36	35	32	26	-1.9
France	20	17	15	13	9	10	8	-3.0
Germany	137	87	83	76	76	75	71	-0.8
Italy	14	11	12	10	10	9	9	-1.4
Netherlands	11	13	11	10	7	7	5	-3.4
Other Western Europe	66	56	56	51	51	49	47	-0.8
Industrialized Asia	**104**	**130**	**135**	**143**	**149**	**154**	**156**	**0.7**
Japan	66	78	81	89	94	99	100	1.0
Australasia	38	52	53	54	55	55	56	0.2
Total Industrialized	**939**	**951**	**943**	**1,002**	**1,041**	**1,063**	**1,086**	**0.7**
EE/FSU								
Former Soviet Union	333	160	168	170	161	148	133	-1.1
Eastern Europe	189	127	113	112	103	92	82	-1.5
Total EE/FSU	**522**	**287**	**280**	**282**	**264**	**241**	**215**	**-1.3**
Developing Countries								
Developing Asia	**704**	**870**	**773**	**984**	**1,185**	**1,381**	**1,615**	**3.6**
China	514	600	495	655	828	1,000	1,195	4.3
India	101	148	156	185	202	216	245	2.2
South Korea	21	33	36	44	49	52	53	1.8
Other Asia	67	88	87	99	106	113	124	1.7
Middle East	**20**	**30**	**29**	**30**	**36**	**37**	**38**	**1.3**
Turkey	16	23	21	23	25	26	26	1.0
Other Middle East	4	7	7	8	11	12	12	2.2
Africa	**74**	**93**	**90**	**95**	**97**	**103**	**108**	**0.9**
Central and South America	**15**	**23**	**22**	**24**	**26**	**28**	**32**	**1.7**
Brazil	9	14	13	15	18	20	24	2.7
Other Central/South America	5	9	9	9	8	8	8	-0.3
Total Developing	**812**	**1,017**	**914**	**1,132**	**1,343**	**1,550**	**1,793**	**3.3**
Total World	**2,274**	**2,254**	**2,137**	**2,417**	**2,648**	**2,854**	**3,094**	**1.8**
Annex I								
Industrialized	935	944	937	992	1,029	1,049	1,071	0.6
EE/FSU	452	259	257	260	244	224	202	-1.1
Total Annex I	**1,387**	**1,203**	**1,194**	**1,252**	**1,274**	**1,273**	**1,273**	**0.3**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table A19; and World Energy Projection System (2002).

Table A14. World Nuclear Generating Capacity by Region and Country, Reference Case, 1999-2020
(Megawatts)

Region/Country	History		Projections			
	1999	2000	2005	2010	2015	2020
Industrialized Countries						
North America	**108,776**	**108,867**	**112,656**	**109,298**	**103,791**	**102,981**
United States	97,470	97,509	97,700	94,342	88,835	88,025
Canada	9,998	9,998	13,596	13,596	13,596	13,596
Mexico	1,308	1,360	1,360	1,360	1,360	1,360
Industrialized Asia	**43,691**	**43,491**	**44,289**	**47,793**	**50,837**	**53,406**
Japan	43,691	43,491	44,289	47,793	50,837	53,406
Western Europe	**125,991**	**125,726**	**123,397**	**120,191**	**113,778**	**103,989**
Belgium	5,712	5,712	5,712	5,712	5,712	3,966
Finland	2,656	2,656	2,656	2,656	2,656	2,656
France	63,103	63,153	62,920	62,920	62,920	64,370
Germany	21,122	21,122	20,142	18,975	17,735	13,134
Netherlands	449	449	449	0	0	0
Spain	7,470	7,512	7,512	7,512	6,913	6,913
Sweden	9,432	9,432	9,432	9,432	6,907	6,077
Switzerland	3,079	3,192	3,192	3,192	2,827	2,115
United Kingdom	12,968	12,498	11,382	9,792	8,108	4,758
Total Industrialized	**278,458**	**278,084**	**280,342**	**277,282**	**268,406**	**260,376**
EE/FSU						
Eastern Europe	**10,605**	**10,675**	**11,692**	**10,060**	**10,060**	**10,710**
Bulgaria	3,538	3,538	2,722	1,906	1,906	1,906
Czech Republic	1,648	1,648	3,481	3,481	3,481	3,481
Hungary	1,729	1,755	1,755	1,755	1,755	1,755
Romania	650	650	650	650	650	1,300
Slovakia	2,408	2,408	2,408	1,592	1,592	1,592
Slovenia	632	676	676	676	676	676
Former Soviet Union	**34,704**	**33,796**	**34,511**	**32,543**	**31,471**	**26,004**
Armenia	376	376	376	0	0	0
Lithuania	2,370	2,370	1,185	0	0	0
Russia	19,843	19,843	21,743	21,336	20,264	14,797
Ukraine	12,115	11,207	11,207	11,207	11,207	11,207
Total EE/FSU	**45,309**	**44,471**	**46,203**	**42,603**	**41,531**	**36,714**

See notes at end of table.

Table A14. World Nuclear Generating Capacity by Region and Country, Reference Case, 1999-2020 (Continued)
(Megawatts)

Region/Country	History		Projections			
	1999	2000	2005	2010	2015	2020
Developing Countries						
Developing Asia	**22,063**	**22,777**	**30,259**	**37,663**	**44,099**	**54,447**
China	2,167	2,177	6,597	9,597	11,587	16,607
India	1,897	2,301	2,503	3,973	4,423	6,451
Korea, North	0	0	0	0	950	950
Korea, South	12,990	12,990	15,850	16,254	19,425	22,125
Pakistan	125	425	425	425	300	900
Taiwan	4,884	4,884	4,884	7,414	7,414	7,414
Central and South America	**1,561**	**2,790**	**2,790**	**2,790**	**2,455**	**3,684**
Argentina	935	935	935	935	600	600
Brazil	626	1,855	1,855	1,855	1,855	3,084
Middle East	**0**	**0**	**1,073**	**1,073**	**2,146**	**2,146**
Iran	0	0	1,073	1,073	2,146	2,146
Africa	**1,842**	**1,800**	**1,800**	**1,800**	**1,930**	**2,060**
South Africa	1,842	1,800	1,800	1,800	1,930	2,060
Total Developing	**25,466**	**27,367**	**35,922**	**43,326**	**50,630**	**62,337**
Total World	**349,233**	**349,922**	**362,467**	**363,211**	**360,567**	**359,427**

Sources: **History:** International Atomic Energy Agency, *Nuclear Power Reactors in the World 2000* (Vienna, Austria, April 2001). **Projections:** Energy Information Administration (EIA), *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table A9; and EIA, Office of Coal, Nuclear, Electric and Alternate Fuels, based on detailed assessments of country-specific nuclear power plants.

Table A15. World Total Energy Consumption in Oil-Equivalent Units by Region, Reference Case, 1990-2020
(Million Tons Oil Equivalent)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**2,522**	**2,841**	**2,916**	**3,258**	**3,540**	**3,813**	**4,066**	**1.6**
United States[a]	2,121	2,383	2,446	2,712	2,913	3,116	3,297	1.4
Canada	275	305	316	346	374	398	422	1.4
Mexico	126	153	155	200	252	299	346	3.9
Western Europe	**1,508**	**1,659**	**1,664**	**1,802**	**1,881**	**1,958**	**2,054**	**1.0**
United Kingdom	234	251	250	269	282	295	308	1.0
France	222	256	258	282	296	309	328	1.1
Germany	373	357	352	387	400	412	428	0.9
Italy	176	201	203	223	237	249	262	1.2
Netherlands	85	96	97	104	108	112	116	0.9
Other Western Europe	419	498	504	538	559	581	612	0.9
Industrialized Asia	**574**	**695**	**704**	**750**	**793**	**836**	**879**	**1.1**
Japan	452	541	547	578	609	640	671	1.0
Australasia	122	153	157	171	184	196	209	1.4
Total Industrialized	**4,604**	**5,194**	**5,284**	**5,810**	**6,215**	**6,607**	**7,000**	**1.3**
EE/FSU								
Former Soviet Union	1,529	975	988	1,112	1,210	1,337	1,439	1.8
Eastern Europe	393	299	283	321	348	382	411	1.8
Total EE/FSU	**1,923**	**1,274**	**1,271**	**1,433**	**1,558**	**1,720**	**1,851**	**1.8**
Developing Countries								
Developing Asia	**1,286**	**1,837**	**1,788**	**2,332**	**2,869**	**3,455**	**4,087**	**4.0**
China	681	890	803	1,080	1,388	1,734	2,127	4.7
India	196	293	307	384	459	549	639	3.6
South Korea	92	173	185	243	270	302	327	2.7
Other Asia	317	481	492	626	752	871	994	3.4
Middle East	**330**	**481**	**487**	**556**	**663**	**768**	**876**	**2.8**
Turkey	50	76	74	85	99	113	127	2.6
Other Middle East	280	405	413	471	564	655	749	2.9
Africa	**235**	**292**	**297**	**352**	**395**	**455**	**510**	**2.6**
Central and South America	**346**	**489**	**498**	**571**	**713**	**898**	**1,086**	**3.8**
Brazil	142	208	215	237	289	353	424	3.3
Other Central/South America	204	282	283	334	424	544	662	4.1
Total Developing	**2,197**	**3,100**	**3,069**	**3,810**	**4,640**	**5,576**	**6,559**	**3.7**
Total World	**8,724**	**9,568**	**9,623**	**11,053**	**12,413**	**13,902**	**15,410**	**2.3**
Annex I								
Industrialized	4,479	5,042	5,129	5,610	5,962	6,308	6,653	1.2
EE/FSU	1,628	1,094	1,092	1,223	1,322	1,456	1,561	1.7
Total Annex I	**6,106**	**6,136**	**6,221**	**6,833**	**7,284**	**7,764**	**8,214**	**1.3**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table A1; and World Energy Projection System (2002).

Table A16. World Population by Region, Reference Case, 1990-2020
(Millions)

Region/Country	History			Projections				Annual Average Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**366**	**397**	**401**	**426**	**446**	**466**	**486**	**0.9**
United States[a]	255	271	273	288	300	313	325	0.8
Canada	28	30	30	32	33	34	36	0.7
Mexico	83	96	97	106	113	119	125	1.2
Western Europe	**377**	**388**	**389**	**391**	**391**	**389**	**387**	**0.0**
United Kingdom	58	59	59	60	60	61	61	0.1
France	57	59	59	60	61	62	62	0.3
Germany	79	82	82	82	81	81	80	-0.1
Italy	57	58	58	57	56	55	54	-0.3
Netherlands	15	16	16	16	16	16	17	0.2
Other Western Europe	112	115	115	116	115	115	114	-0.1
Industrialized Asia	**148**	**153**	**154**	**156**	**158**	**158**	**158**	**0.1**
Japan	124	127	127	128	128	128	126	0.0
Australasia	24	27	27	28	30	31	32	0.8
Total Industrialized	**890**	**938**	**943**	**974**	**995**	**1,014**	**1,031**	**0.4**
EE/FSU								
Former Soviet Union	290	294	292	286	283	280	278	-0.2
Eastern Europe	122	119	121	120	119	118	116	-0.2
Total EE/FSU	**412**	**413**	**413**	**406**	**402**	**398**	**394**	**-0.2**
Developing Countries								
Developing Asia	**2,788**	**3,151**	**3,194**	**3,447**	**3,651**	**3,846**	**4,025**	**1.1**
China	1,155	1,254	1,265	1,321	1,366	1,410	1,446	0.6
India	845	976	993	1,089	1,164	1,230	1,291	1.3
South Korea	43	46	46	48	50	51	51	0.5
Other Asia	745	875	891	989	1,072	1,154	1,237	1.6
Middle East	**191**	**231**	**236**	**268**	**295**	**325**	**355**	**2.0**
Turkey	56	65	66	71	75	79	83	1.1
Other Middle East	135	166	171	196	220	246	272	2.3
Africa	**619**	**757**	**775**	**892**	**997**	**1,110**	**1,231**	**2.2**
Central and South America	**354**	**404**	**410**	**447**	**477**	**507**	**534**	**1.3**
Brazil	148	166	168	181	191	201	211	1.1
Other Central/South America	206	238	242	266	286	305	324	1.4
Total Developing	**3,953**	**4,542**	**4,616**	**5,053**	**5,421**	**5,787**	**6,146**	**1.4**
Total World	**5,255**	**5,893**	**5,972**	**6,433**	**6,817**	**7,199**	**7,570**	**1.1**
Annex I								
Industrialized	807	842	846	868	882	895	906	0.3
EE/FSU	311	307	305	296	288	281	274	-0.5
Total Annex I	**1,118**	**1,149**	**1,151**	**1,163**	**1,170**	**1,176**	**1,180**	**0.1**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

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

Sources: **United States:** Energy Information Administration, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), 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
Nuclear Power Capacity

Table B1. World Total Energy Consumption by Region, High Economic Growth Case, 1990-2020
(Quadrillion Btu)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**100.1**	**112.7**	**115.7**	**131.9**	**145.4**	**158.2**	**171.2**	**1.9**
United States[a]	84.2	94.6	97.0	109.1	119.1	128.7	138.2	1.7
Canada	10.9	12.1	12.5	14.3	15.7	16.8	17.8	1.7
Mexico	5.0	6.1	6.1	8.5	10.6	12.7	15.2	4.4
Western Europe	**59.8**	**65.8**	**66.0**	**73.8**	**78.2**	**82.5**	**88.0**	**1.4**
United Kingdom	9.3	9.9	9.9	11.1	11.8	12.6	13.4	1.4
France	8.8	10.2	10.3	11.6	12.4	13.2	14.2	1.6
Germany	14.8	14.2	14.0	15.9	16.7	17.4	18.3	1.3
Italy	7.0	8.0	8.0	9.2	9.9	10.6	11.2	1.6
Netherlands	3.4	3.8	3.8	4.2	4.4	4.7	4.9	1.2
Other Western Europe	16.6	19.8	20.0	21.8	22.9	24.1	26.0	1.3
Industrialized Asia	**22.8**	**27.6**	**27.9**	**31.0**	**32.9**	**35.0**	**37.1**	**1.4**
Japan	17.9	21.5	21.7	24.0	25.3	26.7	28.2	1.2
Australasia	4.8	6.1	6.2	7.0	7.6	8.2	8.9	1.7
Total Industrialized	**182.7**	**206.1**	**209.7**	**236.8**	**256.5**	**275.7**	**296.3**	**1.7**
EE/FSU								
Former Soviet Union	60.7	38.7	39.2	46.2	52.5	61.3	69.7	2.8
Eastern Europe	15.6	11.9	11.2	12.9	14.8	17.6	20.1	2.8
Total EE/FSU	**76.3**	**50.6**	**50.4**	**59.1**	**67.3**	**78.9**	**89.8**	**2.8**
Developing Countries								
Developing Asia	**51.0**	**72.9**	**70.9**	**103.9**	**135.0**	**172.7**	**215.4**	**5.4**
China	27.0	35.3	31.9	45.7	61.5	80.6	102.8	5.7
India	7.8	11.6	12.2	16.4	20.5	25.4	30.6	4.5
South Korea	3.7	6.9	7.3	9.8	11.3	13.5	15.7	3.7
Other Asia	12.6	19.1	19.5	32.0	41.8	53.2	66.3	6.0
Middle East	**13.1**	**19.1**	**19.3**	**23.8**	**30.2**	**37.3**	**45.9**	**4.2**
Turkey	2.0	3.0	3.0	3.7	4.6	5.5	6.7	4.0
Other Middle East	11.1	16.1	16.4	20.1	25.6	31.8	39.2	4.2
Africa	**9.3**	**11.6**	**11.8**	**15.3**	**18.0**	**21.8**	**25.6**	**3.8**
Central and South America	**13.7**	**19.4**	**19.8**	**26.5**	**34.5**	**44.7**	**55.0**	**5.0**
Brazil	5.7	8.2	8.5	10.3	12.9	15.8	19.0	3.9
Other Central/South America	8.1	11.2	11.2	16.2	21.6	28.9	36.0	5.7
Total Developing	**87.2**	**123.0**	**121.8**	**169.4**	**217.6**	**276.4**	**341.9**	**5.0**
Total World	**346.2**	**379.7**	**381.9**	**465.2**	**541.4**	**631.0**	**728.0**	**3.1**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Energy totals include net imports of coal coke and electricity generated from biomass in the United States. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table B1; and World Energy Projection System (2002).

Table B2. World Total Energy Consumption by Region and Fuel, High Economic Growth Case, 1990-2020
(Quadrillion Btu)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America								
Oil	40.4	44.6	45.8	51.8	58.4	64.7	71.2	2.1
Natural Gas	22.7	26.2	26.8	32.2	36.2	40.5	43.5	2.3
Coal	20.5	23.5	23.5	26.2	28.1	29.5	32.1	1.5
Nuclear	7.0	8.0	8.6	9.3	9.1	8.8	8.8	0.1
Other	9.5	10.7	11.4	12.4	13.7	14.8	15.7	1.5
Total	**100.1**	**112.7**	**115.7**	**131.9**	**145.4**	**158.2**	**171.2**	**1.9**
Western Europe								
Oil	25.8	29.1	28.7	31.6	32.9	34.0	35.1	1.0
Natural Gas	9.7	13.6	14.3	18.6	21.2	24.3	28.9	3.4
Coal	12.4	8.8	8.4	7.9	7.8	7.6	7.0	-0.9
Nuclear	7.4	8.8	8.9	8.9	9.0	8.7	8.2	-0.4
Other	4.5	5.4	5.6	6.7	7.3	8.0	8.8	2.2
Total	**59.8**	**65.8**	**66.0**	**73.8**	**78.2**	**82.5**	**88.0**	**1.4**
Industrialized Asia								
Oil	12.5	13.7	13.9	15.5	16.4	17.1	17.8	1.2
Natural Gas	2.5	3.6	3.8	4.3	4.5	5.1	5.9	2.1
Coal	4.2	5.3	5.4	6.0	6.3	6.5	6.7	1.0
Nuclear	2.0	3.2	3.2	3.4	3.7	4.0	4.3	1.5
Other	1.6	1.7	1.7	1.8	1.9	2.2	2.4	1.6
Total	**22.8**	**27.6**	**27.9**	**31.0**	**32.9**	**35.0**	**37.1**	**1.4**
Total Industrialized								
Oil	78.7	87.4	88.4	98.9	107.7	115.8	124.1	1.6
Natural Gas	35.0	43.5	44.8	55.1	61.9	69.8	78.3	2.7
Coal	37.1	37.5	37.3	40.1	42.1	43.6	45.8	1.0
Nuclear	16.3	20.0	20.6	21.6	21.8	21.6	21.3	0.1
Other	15.6	17.9	18.6	21.0	23.0	24.9	26.9	1.8
Total	**182.7**	**206.1**	**209.7**	**236.8**	**256.5**	**275.7**	**296.3**	**1.7**
EE/FSU								
Oil	21.0	10.9	10.8	14.6	17.8	22.1	25.8	4.2
Natural Gas	28.8	22.7	22.9	26.3	31.1	37.9	45.2	3.3
Coal	20.8	11.4	11.1	11.6	11.4	11.1	10.5	-0.3
Nuclear	2.9	2.7	2.7	3.3	3.3	3.5	3.4	1.0
Other	2.8	3.0	3.0	3.3	3.7	4.3	5.0	2.5
Total	**76.3**	**50.6**	**50.4**	**59.1**	**67.3**	**78.9**	**89.8**	**2.8**
Developing Countries								
Developing Asia								
Oil	16.0	26.7	27.7	38.8	50.8	66.2	82.7	5.4
Natural Gas	3.2	6.0	6.4	12.8	17.8	24.4	32.2	8.0
Coal	27.7	34.5	30.7	42.4	53.5	65.6	80.1	4.7
Nuclear	0.9	1.5	1.6	2.5	3.4	4.2	5.6	6.1
Other	3.2	4.3	4.6	7.3	9.6	12.3	14.8	5.7
Total	**51.0**	**72.9**	**70.9**	**103.9**	**135.0**	**172.7**	**215.4**	**5.4**

See notes at end of table.

Table B2. World Total Energy Consumption by Region and Fuel, High Economic Growth Case, 1990-2020 (Continued)
(Quadrillion Btu)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Developing Countries (Continued)								
Middle East								
Oil	8.1	10.4	10.5	12.7	15.1	18.0	21.6	3.5
Natural Gas	3.9	6.9	7.1	8.9	12.4	15.9	20.1	5.1
Coal	0.8	1.2	1.1	1.3	1.6	1.8	2.0	2.7
Nuclear	0.0	0.0	0.0	0.0	0.1	0.1	0.2	—
Other	0.4	0.6	0.5	0.8	1.0	1.5	2.0	6.6
Total	**13.1**	**19.1**	**19.3**	**23.8**	**30.2**	**37.3**	**45.9**	**4.2**
Africa								
Oil	4.2	5.1	5.2	7.4	9.2	11.3	13.7	4.7
Natural Gas	1.5	2.0	2.1	2.7	3.2	4.0	4.7	3.9
Coal	3.0	3.7	3.6	4.2	4.5	5.0	5.5	2.0
Nuclear	0.1	0.1	0.1	0.1	0.1	0.2	0.2	2.0
Other	0.6	0.7	0.7	0.9	1.0	1.3	1.5	3.6
Total	**9.3**	**11.6**	**11.8**	**15.3**	**18.0**	**21.8**	**25.6**	**3.8**
Central and South America								
Oil	7.0	9.4	9.5	12.4	15.8	19.2	23.1	4.3
Natural Gas	2.2	3.4	3.5	5.7	9.4	15.1	20.3	8.7
Coal	0.6	0.9	0.9	1.1	1.3	1.4	1.6	2.8
Nuclear	0.1	0.1	0.1	0.2	0.2	0.2	0.3	4.9
Other	3.9	5.6	5.7	7.0	7.8	8.8	9.7	2.6
Total	**13.7**	**19.4**	**19.8**	**26.5**	**34.5**	**44.7**	**55.0**	**5.0**
Total Developing Countries								
Oil	35.2	51.5	52.9	71.4	90.9	114.7	141.2	4.8
Natural Gas	10.8	18.3	19.2	30.1	42.8	59.5	77.4	6.9
Coal	32.1	40.3	36.3	49.0	60.8	73.8	89.1	4.4
Nuclear	1.1	1.7	1.9	2.8	3.8	4.8	6.3	5.9
Other	8.0	11.1	11.5	16.1	19.4	23.8	28.0	4.3
Total	**87.2**	**123.0**	**121.8**	**169.4**	**217.6**	**276.4**	**341.9**	**5.0**
Total World								
Oil	134.9	149.8	152.2	184.9	216.3	252.6	291.0	3.1
Natural Gas	74.5	84.5	86.9	111.5	135.9	167.2	200.8	4.1
Coal	90.0	89.3	84.8	100.7	114.3	128.4	145.4	2.6
Nuclear	20.4	24.4	25.3	27.8	28.9	29.9	30.9	1.0
Other	26.5	32.0	33.1	40.3	46.1	53.0	59.8	2.9
Total	**346.2**	**379.7**	**381.9**	**465.2**	**541.4**	**631.0**	**728.0**	**3.1**

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 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table B1; and World Energy Projection System (2002).

Table B3. World Gross Domestic Product (GDP) by Region, High Economic Growth Case, 1990-2020
(Billion 1997 Dollars)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**7,723**	**9,760**	**10,165**	**13,417**	**16,433**	**19,770**	**23,595**	**4.1**
United States[a]	6,836	8,675	9,029	11,909	14,552	17,454	20,754	4.0
Canada	555	665	699	900	1,077	1,246	1,411	3.4
Mexico	332	421	437	608	804	1,070	1,430	5.8
Western Europe	**7,597**	**8,731**	**8,944**	**11,076**	**13,036**	**15,260**	**17,794**	**3.3**
United Kingdom	1,146	1,353	1,384	1,750	2,077	2,493	2,944	3.7
France	1,299	1,455	1,499	1,870	2,217	2,560	2,938	3.3
Germany	1,879	2,156	2,187	2,674	3,118	3,623	4,203	3.2
Italy	1,079	1,188	1,207	1,469	1,719	2,001	2,317	3.2
Netherlands	317	392	407	505	596	700	819	3.4
Other Western Europe	1,877	2,187	2,260	2,809	3,310	3,882	4,573	3.4
Industrialized Asia	**4,054**	**4,765**	**4,821**	**5,530**	**6,313**	**7,285**	**8,336**	**2.6**
Japan	3,673	4,271	4,304	4,887	5,551	6,380	7,256	2.5
Australasia	381	494	516	643	762	905	1,080	3.6
Total Industrialized	**19,374**	**23,256**	**23,930**	**30,023**	**35,783**	**42,315**	**49,726**	**3.5**
EE/FSU								
Former Soviet Union	1,009	545	569	838	1,162	1,751	2,447	7.2
Eastern Europe	348	358	363	574	826	1,181	1,656	7.5
Total EE/FSU	**1,357**	**903**	**932**	**1,411**	**1,988**	**2,932**	**4,104**	**7.3**
Developing Countries								
Developing Asia	**1,739**	**2,975**	**3,165**	**4,925**	**7,119**	**10,077**	**14,093**	**7.4**
China	427	968	1,037	1,730	2,654	3,911	5,693	8.4
India	268	445	473	727	1,027	1,444	2,018	7.2
South Korea	297	445	493	711	983	1,346	1,827	6.4
Other Asia	748	1,118	1,162	1,757	2,454	3,376	4,554	6.7
Middle East	**379**	**580**	**577**	**806**	**1,084**	**1,476**	**2,023**	**6.2**
Turkey	140	196	186	262	352	477	645	6.1
Other Middle East	239	384	391	544	731	999	1,377	6.2
Africa	**405**	**485**	**499**	**708**	**935**	**1,211**	**1,554**	**5.6**
Central and South America	**1,136**	**1,467**	**1,452**	**2,067**	**2,770**	**3,668**	**4,832**	**5.9**
Brazil	674	810	816	1,166	1,575	2,089	2,761	6.0
Other Central/South America	462	657	636	900	1,195	1,578	2,071	5.8
Total Developing	**3,660**	**5,507**	**5,693**	**8,505**	**11,907**	**16,431**	**22,501**	**6.8**
Total World	**24,392**	**29,665**	**30,555**	**39,940**	**49,678**	**61,679**	**76,330**	**4.5**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

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

Sources: DRI-WEFA, *World Economic Outlook*, Vol. 1 (Lexington, MA, 3rd Quarter 2001); Energy Information Administration (EIA), *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table B20; and EIA, World Energy Projection System (2002).

Table B4. World Oil Consumption by Region, High Economic Growth Case, 1990-2020
(Million Barrels per Day)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**20.4**	**22.7**	**23.4**	**26.5**	**29.8**	**33.0**	**36.3**	**2.1**
United States[a]	17.0	18.9	19.5	21.6	24.1	26.4	28.5	1.8
Canada	1.7	1.9	1.9	2.2	2.4	2.5	2.6	1.4
Mexico	1.7	1.9	2.0	2.7	3.3	4.1	5.1	4.7
Western Europe	**12.5**	**14.1**	**13.9**	**15.3**	**15.9**	**16.5**	**17.0**	**1.0**
United Kingdom	1.8	1.8	1.7	2.1	2.2	2.3	2.4	1.7
France	1.8	2.0	2.0	2.2	2.4	2.4	2.5	1.1
Germany	2.7	2.9	2.8	3.2	3.3	3.4	3.4	0.9
Italy	1.9	2.1	2.0	2.2	2.3	2.3	2.4	0.8
Netherlands	0.7	0.8	0.8	0.9	0.9	1.0	1.0	1.0
Other Western Europe	3.6	4.5	4.5	4.7	4.9	5.1	5.2	0.7
Industrialized Asia	**6.2**	**6.8**	**6.9**	**7.6**	**8.1**	**8.5**	**8.8**	**1.2**
Japan	5.1	5.5	5.6	6.1	6.5	6.6	6.8	0.9
Australasia	1.0	1.3	1.3	1.5	1.7	1.8	2.0	2.1
Total Industrialized	**39.0**	**43.6**	**44.2**	**49.5**	**53.8**	**57.9**	**62.1**	**1.6**
EE/FSU								
Former Soviet Union	8.4	3.8	3.7	5.3	6.5	8.3	9.7	4.7
Eastern Europe	1.6	1.4	1.5	1.7	2.0	2.3	2.6	2.8
Total EE/FSU	**10.0**	**5.2**	**5.2**	**7.0**	**8.5**	**10.6**	**12.3**	**4.2**
Developing Countries								
Developing Asia	**7.6**	**12.8**	**13.3**	**18.6**	**24.4**	**31.8**	**39.7**	**5.4**
China	2.3	4.1	4.3	5.7	7.6	10.0	12.8	5.3
India	1.2	1.8	1.9	2.7	3.6	4.8	5.9	5.5
South Korea	1.0	2.0	2.0	2.5	2.9	3.3	3.7	2.8
Other Asia	3.1	4.9	5.0	7.8	10.3	13.6	17.3	6.1
Middle East	**3.9**	**5.0**	**5.0**	**6.1**	**7.2**	**8.6**	**10.3**	**3.5**
Turkey	0.5	0.6	0.6	0.9	1.0	1.3	1.5	4.4
Other Middle East	3.4	4.3	4.4	5.2	6.2	7.4	8.8	3.3
Africa	**2.1**	**2.5**	**2.5**	**3.6**	**4.5**	**5.5**	**6.7**	**4.7**
Central and South America	**3.4**	**4.6**	**4.7**	**6.1**	**7.7**	**9.4**	**11.3**	**4.3**
Brazil	1.3	1.9	2.0	2.3	2.9	3.5	4.4	4.0
Other Central/South America	2.1	2.7	2.7	3.8	4.9	5.8	6.9	4.5
Total Developing	**17.0**	**24.8**	**25.5**	**34.4**	**43.8**	**55.2**	**68.0**	**4.8**
Total World	**66.0**	**73.6**	**74.9**	**90.8**	**106.1**	**123.8**	**142.4**	**3.1**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Energy totals include net imports of coal coke and electricity generated from biomass in the United States. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table B21; and World Energy Projection System (2002).

Table B5. World Natural Gas Consumption by Region, High Economic Growth Case, 1990-2020
(Trillion Cubic Feet)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**22.0**	**25.4**	**26.1**	**31.3**	**35.3**	**39.4**	**42.4**	**2.3**
United States[a]	18.7	21.3	21.7	26.0	29.1	32.6	35.0	2.3
Canada	2.4	2.9	3.1	3.5	3.8	4.2	4.6	1.9
Mexico	0.9	1.3	1.3	1.9	2.3	2.6	2.8	3.9
Western Europe	**10.1**	**13.4**	**14.0**	**18.2**	**20.7**	**23.6**	**28.0**	**3.4**
United Kingdom	2.1	3.1	3.3	3.9	4.5	5.1	6.0	3.0
France	1.0	1.3	1.3	1.9	2.2	2.6	3.2	4.2
Germany	2.7	3.0	3.0	4.2	4.6	5.1	6.3	3.5
Italy	1.7	2.2	2.4	3.0	3.4	3.9	4.3	2.8
Netherlands	1.5	1.8	1.7	2.0	2.2	2.3	2.5	1.8
Other Western Europe	1.2	2.0	2.3	3.3	3.7	4.6	5.8	4.6
Industrialized Asia	**2.6**	**3.5**	**3.6**	**4.1**	**4.3**	**4.9**	**5.6**	**2.2**
Japan	1.9	2.5	2.6	3.0	3.0	3.4	4.0	2.0
Australasia	0.8	0.9	1.0	1.2	1.3	1.5	1.7	2.7
Total Industrialized	**34.8**	**42.3**	**43.7**	**53.6**	**60.3**	**67.9**	**76.1**	**2.7**
EE/FSU								
Former Soviet Union	25.0	19.9	20.1	22.7	26.2	31.2	36.7	2.9
Eastern Europe	3.1	2.5	2.4	3.1	4.4	6.1	7.8	5.7
Total EE/FSU	**28.1**	**22.4**	**22.5**	**25.9**	**30.6**	**37.3**	**44.5**	**3.3**
Developing Countries								
Developing Asia	**3.0**	**5.6**	**6.0**	**12.0**	**16.7**	**22.7**	**29.9**	**7.9**
China	0.5	0.8	0.9	2.0	3.2	5.3	7.9	11.1
India	0.4	0.8	0.8	1.2	1.8	2.6	3.2	7.1
South Korea	0.1	0.5	0.6	1.2	1.5	2.1	2.7	7.5
Other Asia	1.9	3.6	3.8	7.6	10.2	12.8	16.1	7.1
Middle East	**3.7**	**6.6**	**6.8**	**8.5**	**11.8**	**15.2**	**19.2**	**5.1**
Turkey	0.1	0.4	0.4	0.5	0.7	1.0	1.4	5.6
Other Middle East	3.6	6.2	6.3	8.0	11.1	14.1	17.8	5.0
Africa	**1.4**	**1.8**	**2.0**	**2.5**	**2.9**	**3.7**	**4.4**	**8.7**
Central and South America	**2.0**	**3.1**	**3.2**	**5.2**	**8.7**	**13.9**	**18.6**	**8.7**
Brazil	0.1	0.2	0.2	0.6	1.5	2.7	3.6	13.9
Other Central/South America	1.9	2.9	3.0	4.6	7.2	11.2	15.0	7.9
Total Developing	**10.1**	**17.2**	**18.0**	**28.3**	**40.1**	**55.5**	**72.1**	**6.8**
Total World	**72.9**	**81.9**	**84.2**	**107.8**	**131.0**	**160.7**	**192.7**	**4.0**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. 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 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table B13; and World Energy Projection System (2002).

Table B6. World Coal Consumption by Region, High Economic Growth Case, 1990-2020
(Million Short Tons)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**959**	**1,121**	**1,122**	**1,273**	**1,375**	**1,449**	**1,585**	**1.7**
United States[a]	895	1,040	1,045	1,181	1,271	1,335	1,462	1.6
Canada	55	66	63	69	77	83	88	1.5
Mexico	9	15	13	22	27	31	36	4.9
Western Europe	**894**	**566**	**546**	**514**	**508**	**497**	**469**	**-0.7**
United Kingdom	119	70	65	63	61	57	47	-1.5
France	35	29	26	23	17	18	15	-2.6
Germany	528	269	258	245	249	247	236	-0.4
Italy	23	19	19	18	18	16	16	-0.9
Netherlands	15	16	14	13	9	9	7	-3.0
Other Western Europe	173	164	165	152	153	149	147	-0.5
Industrialized Asia	**231**	**287**	**295**	**323**	**337**	**350**	**359**	**0.9**
Japan	125	144	149	171	181	191	195	1.3
Australasia	106	142	145	152	156	159	164	0.6
Total Industrialized	**2,084**	**1,974**	**1,963**	**2,110**	**2,220**	**2,295**	**2,413**	**1.0**
EE/FSU								
Former Soviet Union	848	396	414	442	435	425	403	-0.1
Eastern Europe	527	414	363	365	356	344	324	-0.5
Total EE/FSU	**1,375**	**810**	**778**	**807**	**791**	**769**	**727**	**-0.3**
Developing Countries								
Developing Asia	**1,583**	**1,903**	**1,686**	**2,335**	**2,942**	**3,606**	**4,405**	**4.7**
China	1,124	1,300	1,075	1,516	2,005	2,541	3,156	5.3
India	242	333	348	446	505	563	659	3.1
South Korea	42	60	65	82	93	106	116	2.8
Other Asia	175	210	197	291	339	397	474	4.3
Middle East	**66**	**99**	**96**	**109**	**137**	**153**	**167**	**2.7**
Turkey	60	86	84	97	114	125	136	2.4
Other Middle East	6	12	12	12	23	27	31	4.5
Africa	**152**	**181**	**177**	**204**	**218**	**245**	**268**	**2.0**
Central and South America	**26**	**42**	**41**	**51**	**58**	**65**	**74**	**2.8**
Brazil	17	28	27	32	40	45	53	3.2
Other Central/South America	9	15	14	19	18	20	21	2.1
Total Developing	**1,827**	**2,226**	**2,000**	**2,699**	**3,355**	**4,069**	**4,914**	**4.4**
Total World	**5,287**	**5,009**	**4,740**	**5,615**	**6,366**	**7,134**	**8,054**	**2.6**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country. 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 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table B16; and World Energy Projection System (2002).

Table B7. World Nuclear Energy Consumption by Region, High Economic Growth Case, 1990-2020
(Billion Kilowatthours)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**649**	**750**	**808**	**865**	**847**	**820**	**818**	**0.1**
United States[a]	577	674	728	759	737	707	702	-0.2
Canada	69	68	70	96	100	103	106	2.0
Mexico	3	9	10	10	10	10	10	0.3
Western Europe	**703**	**836**	**846**	**858**	**864**	**841**	**791**	**-0.3**
United Kingdom	59	95	91	70	63	56	34	-4.6
France	298	369	375	408	424	437	463	1.0
Germany	145	154	161	160	154	147	112	-1.7
Italy	0	0	0	0	0	0	0	—
Netherlands	3	4	4	4	0	0	0	-100.0
Other Western Europe	198	215	215	216	222	202	182	-0.8
Industrialized Asia	**192**	**316**	**309**	**333**	**363**	**394**	**421**	**1.5**
Japan	192	316	309	333	363	394	421	1.5
Australasia	0	0	0	0	0	0	0	—
Total Industrialized	**1,544**	**1,902**	**1,962**	**2,055**	**2,074**	**2,056**	**2,030**	**0.2**
EE/FSU								
Former Soviet Union	201	183	190	217	222	233	208	0.4
Eastern Europe	54	61	60	82	78	86	99	2.4
Total EE/FSU	**256**	**244**	**250**	**299**	**300**	**319**	**308**	**1.0**
Developing Countries								
Developing Asia	**88**	**145**	**160**	**248**	**331**	**417**	**548**	**12.2**
China	0	13	14	55	83	106	159	12.2
India	6	11	11	16	29	35	55	7.7
South Korea	50	85	98	128	137	177	218	3.9
Other Asia	32	36	37	49	82	99	116	5.6
Middle East	**0**	**0**	**0**	**0**	**6**	**15**	**17**	**—**
Turkey	0	0	0	0	0	0	0	—
Other Middle East	0	0	0	0	6	15	17	—
Africa	**8**	**14**	**13**	**13**	**14**	**17**	**19**	**2.0**
Central and South America	**9**	**10**	**11**	**18**	**19**	**18**	**29**	**4.9**
Brazil	2	3	4	11	12	13	23	9.0
Other Central/South America	7	7	7	6	7	5	6	-0.8
Total Developing	**105**	**169**	**184**	**279**	**371**	**467**	**613**	**5.9**
Total World	**1,905**	**2,315**	**2,396**	**2,634**	**2,745**	**2,841**	**2,950**	**1.0**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table B8; and World Energy Projection System (2002).

Table B8. World Consumption of Hydroelectricity and Other Renewable Energy by Region, High Economic Growth Case, 1990-2020
(Quadrillion Btu)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**9.5**	**10.7**	**11.4**	**12.4**	**13.7**	**14.8**	**15.7**	**1.5**
United States[a]	6.1	6.9	7.3	8.1	8.5	9.3	9.9	1.4
Canada	3.1	3.5	3.6	3.8	4.3	4.6	4.8	1.4
Mexico	0.3	0.4	0.4	0.5	0.8	1.0	1.0	4.0
Western Europe	**4.5**	**5.4**	**5.6**	**6.7**	**7.3**	**8.0**	**8.8**	**2.2**
United Kingdom	0.1	0.1	0.1	0.3	0.4	0.4	0.5	6.0
France	0.6	0.7	0.8	0.2	0.3	0.4	0.4	-3.1
Germany	0.3	0.3	0.4	0.6	0.8	0.9	1.0	5.2
Italy	0.4	0.5	0.6	1.2	1.2	1.4	1.5	4.6
Netherlands	0.0	0.0	0.0	0.3	0.4	0.4	0.4	10.7
Other Western Europe	3.2	3.7	3.7	4.1	4.3	4.5	5.0	1.5
Industrialized Asia	**1.6**	**1.7**	**1.7**	**1.8**	**1.9**	**2.2**	**2.4**	**1.6**
Japan	1.1	1.2	1.2	1.3	1.3	1.5	1.6	1.6
Australasia	0.4	0.5	0.5	0.6	0.6	0.7	0.7	1.8
Total Industrialized	**15.6**	**17.9**	**18.6**	**21.0**	**23.0**	**24.9**	**26.9**	**1.8**
EE/FSU								
Former Soviet Union	2.4	2.3	2.3	2.6	2.8	3.1	3.4	1.8
Eastern Europe	0.4	0.6	0.6	0.7	0.9	1.2	1.6	4.5
Total EE/FSU	**2.8**	**3.0**	**3.0**	**3.3**	**3.7**	**4.3**	**5.0**	**2.5**
Developing Countries								
Developing Asia	**3.2**	**4.3**	**4.6**	**7.3**	**9.6**	**12.3**	**14.8**	**5.7**
China	1.3	2.1	2.3	3.6	4.8	6.3	8.0	6.1
India	0.7	0.8	0.9	1.2	1.5	1.8	2.0	4.2
South Korea	0.0	0.0	0.0	0.1	0.1	0.2	0.3	8.9
Other Asia	1.1	1.3	1.4	2.4	3.2	4.0	4.5	5.8
Middle East	**0.4**	**0.6**	**0.5**	**0.8**	**1.0**	**1.5**	**2.0**	**6.6**
Turkey	0.2	0.4	0.4	0.4	0.5	0.6	0.7	3.3
Other Middle East	0.1	0.2	0.2	0.4	0.5	0.9	1.3	10.2
Africa	**0.6**	**0.7**	**0.7**	**0.9**	**1.0**	**1.3**	**1.5**	**3.6**
Central and South America	**3.9**	**5.6**	**5.7**	**7.0**	**7.8**	**8.8**	**9.7**	**2.6**
Brazil	2.2	3.1	3.3	4.1	4.6	4.8	4.9	2.0
Other Central/South America	1.7	2.5	2.4	2.9	3.2	4.0	4.8	3.3
Total Developing	**8.0**	**11.1**	**11.5**	**16.1**	**19.4**	**23.8**	**28.0**	**4.3**
Total World	**26.5**	**32.0**	**33.1**	**40.3**	**46.1**	**53.0**	**59.8**	**2.9**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country. U.S. totals include net electricity imports, methanol, and liquid hydrogen.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table B1; and World Energy Projection System (2002).

Table B9. World Net Electricity Consumption by Region, High Economic Growth Case, 1990-2020
(Billion Kilowatthours)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**3,362**	**4,046**	**3,904**	**4,668**	**5,264**	**5,857**	**6,456**	**2.4**
United States[a]	2,817	3,400	3,236	3,833	4,284	4,735	5,173	2.3
Canada	438	485	498	581	646	700	752	2.0
Mexico	107	162	171	254	334	422	531	5.5
Western Europe	**2,077**	**2,399**	**2,435**	**2,842**	**3,111**	**3,393**	**3,744**	**2.1**
United Kingdom	287	330	333	390	423	459	493	1.9
France	326	394	399	444	490	534	594	1.9
Germany	489	492	495	590	642	692	756	2.0
Italy	222	266	272	349	395	444	496	2.9
Netherlands	72	95	98	114	125	137	150	2.0
Other Western Europe	681	822	838	954	1,036	1,128	1,255	1.9
Industrialized Asia	**945**	**1,158**	**1,178**	**1,362**	**1,474**	**1,592**	**1,715**	**1.8**
Japan	765	932	947	1,084	1,168	1,258	1,349	1.7
Australasia	181	226	231	278	306	334	366	2.2
Total Industrialized	**6,385**	**7,604**	**7,517**	**8,872**	**9,849**	**10,842**	**11,915**	**2.2**
EE/FSU								
Former Soviet Union	1,488	1,068	1,075	1,243	1,418	1,666	1,904	2.8
Eastern Europe	418	390	377	442	516	617	712	3.1
Total EE/FSU	**1,906**	**1,459**	**1,452**	**1,685**	**1,934**	**2,283**	**2,616**	**2.8**
Developing Countries								
Developing Asia	**1,259**	**2,175**	**2,319**	**3,217**	**4,267**	**5,573**	**7,103**	**5.5**
China	551	1,013	1,084	1,436	2,001	2,722	3,602	5.9
India	257	396	424	555	699	878	1,069	4.5
South Korea	93	207	233	294	344	415	487	3.6
Other Asia	357	560	578	932	1,223	1,558	1,944	5.9
Middle East	**263**	**470**	**494**	**578**	**742**	**928**	**1,155**	**4.1**
Turkey	51	102	106	134	167	205	250	4.2
Other Middle East	213	368	388	444	575	724	904	4.1
Africa	**287**	**361**	**367**	**504**	**629**	**810**	**980**	**4.8**
Central and South America	**449**	**656**	**684**	**899**	**1,176**	**1,529**	**1,891**	**5.0**
Brazil	229	334	354	461	588	736	898	4.5
Other Central/South America	220	322	330	438	588	794	993	5.4
Total Developing	**2,258**	**3,663**	**3,863**	**5,198**	**6,815**	**8,840**	**11,128**	**5.2**
Total World	**10,549**	**12,725**	**12,833**	**15,756**	**18,598**	**21,965**	**25,659**	**3.4**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Electricity consumption equals generation plus imports minus exports minus distribution losses.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table B2; and World Energy Projection System (2002).

Table B10. World Carbon Dioxide Emissions by Region, High Economic Growth Case, 1990-2020
(Million Metric Tons Carbon Equivalent)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**1,562**	**1,742**	**1,767**	**2,023**	**2,244**	**2,453**	**2,678**	**2.0**
United States[a]	1,352	1,495	1,517	1,714	1,887	2,046	2,215	1.8
Canada	126	146	150	168	183	196	208	1.6
Mexico	84	101	101	141	174	211	256	4.5
Western Europe	**930**	**947**	**940**	**1,041**	**1,095**	**1,153**	**1,227**	**1.3**
United Kingdom	164	154	151	174	186	197	209	1.6
France	102	110	109	123	129	138	149	1.5
Germany	271	237	230	255	266	275	291	1.1
Italy	112	122	121	137	147	154	162	1.4
Netherlands	58	66	64	69	70	74	76	0.8
Other Western Europe	223	260	264	284	298	315	340	1.2
Industrialized Asia	**357**	**412**	**422**	**469**	**496**	**523**	**550**	**1.3**
Japan	269	300	307	342	359	375	392	1.2
Australasia	88	112	115	127	137	147	159	1.5
Total Industrialized	**2,849**	**3,101**	**3,129**	**3,534**	**3,836**	**4,129**	**4,456**	**0.0**
EE/FSU								
Former Soviet Union	1,036	599	607	718	814	950	1,080	2.8
Eastern Europe	301	217	203	224	250	285	313	2.1
Total EE/FSU	**1,337**	**816**	**810**	**942**	**1,064**	**1,235**	**1,393**	**2.6**
Developing Countries								
Developing Asia	**1,053**	**1,435**	**1,361**	**1,950**	**2,516**	**3,192**	**3,966**	**5.2**
China	617	765	669	940	1,255	1,629	2,058	5.5
India	153	231	242	321	392	478	574	4.2
South Korea	61	101	107	142	164	193	220	3.5
Other Asia	223	338	343	547	704	891	1,114	5.8
Middle East	**231**	**325**	**330**	**401**	**503**	**613**	**747**	**4.0**
Turkey	35	50	50	63	77	92	110	3.8
Other Middle East	196	275	280	338	426	521	637	4.0
Africa	**179**	**216**	**218**	**281**	**328**	**394**	**460**	**3.6**
Central and South America	**178**	**246**	**249**	**339**	**459**	**607**	**759**	**5.4**
Brazil	62	87	88	109	146	191	240	4.9
Other Central/South America	116	159	162	230	314	416	519	5.7
Total Developing	**1,641**	**2,222**	**2,158**	**2,971**	**3,806**	**4,806**	**5,932**	**4.9**
Total World	**5,827**	**6,139**	**6,097**	**7,446**	**8,706**	**10,170**	**11,781**	**3.2**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. The U.S. numbers include carbon dioxide emissions attributable to renewable energy sources.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table B19; and World Energy Projection System (2002).

Table B11. World Carbon Dioxide Emissions from Oil Use by Region, High Economic Growth Case, 1990-2020
(Million Metric Tons Carbon Equivalent)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**716**	**775**	**793**	**894**	**1,008**	**1,120**	**1,235**	**2.1**
United States[a]	590	635	650	714	799	876	948	1.8
Canada	61	66	68	77	83	87	90	1.4
Mexico	65	74	76	103	127	157	197	4.7
Western Europe	**474**	**525**	**517**	**570**	**592**	**611**	**632**	**1.0**
United Kingdom	66	65	63	77	81	85	89	1.7
France	67	72	72	79	84	87	90	1.1
Germany	103	107	104	117	120	123	126	0.9
Italy	74	78	74	83	85	87	89	0.8
Netherlands	27	30	31	33	35	37	38	1.0
Other Western Europe	138	172	173	181	188	193	200	0.7
Industrialized Asia	**217**	**230**	**233**	**259**	**275**	**288**	**299**	**1.2**
Japan	179	183	185	204	215	221	225	0.9
Australasia	38	46	48	55	61	67	74	2.1
Total Industrialized	**1,407**	**1,529**	**1,543**	**1,722**	**1,875**	**2,019**	**2,166**	**1.6**
EE/FSU								
Former Soviet Union	334	148	146	207	254	323	380	4.7
Eastern Europe	66	55	55	64	75	88	98	2.8
Total EE/FSU	**400**	**202**	**201**	**271**	**330**	**411**	**479**	**4.2**
Developing Countries								
Developing Asia	**304**	**479**	**496**	**696**	**911**	**1,187**	**1,484**	**5.4**
China	94	152	160	209	280	371	474	5.3
India	45	70	73	101	136	184	226	5.5
South Korea	38	60	62	77	89	101	112	2.8
Other Asia	127	197	201	309	406	530	671	5.9
Middle East	**155**	**195**	**198**	**239**	**284**	**339**	**406**	**3.5**
Turkey	17	22	22	30	36	44	53	4.4
Other Middle East	138	173	177	210	247	295	353	3.4
Africa	**83**	**95**	**97**	**138**	**172**	**211**	**256**	**4.7**
Central and South America	**132**	**173**	**176**	**230**	**292**	**355**	**427**	**4.3**
Brazil	51	70	71	84	104	128	160	4.0
Other Central/South America	81	104	105	146	188	226	267	4.5
Total Developing	**674**	**942**	**968**	**1,303**	**1,658**	**2,091**	**2,573**	**4.8**
Total World	**2,482**	**2,673**	**2,712**	**3,297**	**3,863**	**4,520**	**5,218**	**3.2**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table B19; and World Energy Projection System (2002).

Table B12. World Carbon Dioxide Emissions from Natural Gas Use by Region, High Economic Growth Case, 1990-2020
(Million Metric Tons Carbon Equivalent)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**326**	**377**	**381**	**461**	**518**	**580**	**623**	**2.4**
United States[a]	277	315	317	381	427	479	513	2.3
Canada	35	42	46	51	56	62	67	1.9
Mexico	15	20	19	28	35	40	43	3.9
Western Europe	**140**	**196**	**206**	**268**	**306**	**349**	**416**	**3.4**
United Kingdom	30	47	50	60	68	78	92	3.0
France	16	21	21	30	36	41	50	3.5
Germany	32	42	43	59	65	72	89	3.5
Italy	25	32	35	44	51	57	64	2.8
Netherlands	20	23	22	25	28	30	32	1.8
Other Western Europe	18	31	35	51	58	71	89	4.6
Industrialized Asia	**36**	**52**	**54**	**62**	**65**	**73**	**85**	**2.1**
Japan	24	38	40	45	45	51	60	2.0
Australasia	12	14	14	17	20	22	25	2.7
Total Industrialized	**503**	**626**	**641**	**790**	**889**	**1,002**	**1,123**	**2.7**
EE/FSU								
Former Soviet Union	369	291	294	332	383	455	537	2.9
Eastern Europe	46	36	35	46	65	90	114	5.7
Total EE/FSU	**414**	**327**	**329**	**378**	**448**	**545**	**651**	**3.3**
Developing Countries								
Developing Asia	**45**	**86**	**92**	**184**	**256**	**352**	**464**	**8.0**
China	8	13	14	33	53	89	131	11.1
India	7	13	12	21	30	42	52	7.1
South Korea	2	8	10	19	24	33	44	7.5
Other Asia	29	53	56	111	150	188	236	7.1
Middle East	**56**	**100**	**102**	**129**	**178**	**229**	**290**	**5.1**
Turkey	2	6	7	8	11	16	21	5.6
Other Middle East	54	94	96	121	167	213	269	5.0
Africa	**22**	**29**	**31**	**39**	**45**	**58**	**68**	**3.9**
Central and South America	**32**	**49**	**51**	**82**	**136**	**217**	**292**	**8.7**
Brazil	2	3	4	9	22	40	54	13.9
Other Central/South America	30	46	47	73	114	177	237	8.0
Total Developing	**155**	**263**	**276**	**434**	**616**	**856**	**1,114**	**6.9**
Total World	**1,072**	**1,216**	**1,247**	**1,602**	**1,953**	**2,404**	**2,888**	**4.1**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.
Notes: EE/FSU = Eastern Europe/Former Soviet Union.
Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table B19; and World Energy Projection System (2002).

Table B13. World Carbon Dioxide Emissions from Coal Use by Region, High Economic Growth Case, 1990-2020
(Million Metric Tons Carbon Equivalent)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**520**	**595**	**592**	**669**	**718**	**754**	**820**	**1.6**
United States[a]	485	550	549	619	661	692	754	1.5
Canada	31	38	36	40	44	47	50	1.5
Mexico	4	7	6	10	12	14	16	4.9
Western Europe	**315**	**225**	**216**	**203**	**198**	**192**	**179**	**-0.9**
United Kingdom	68	42	39	38	37	34	28	-1.5
France	20	17	15	14	10	10	9	-2.6
Germany	137	87	83	79	81	80	76	-0.4
Italy	14	11	12	11	11	10	10	-0.9
Netherlands	11	13	11	10	7	7	6	-3.0
Other Western Europe	66	56	56	52	52	51	50	-0.5
Industrialized Asia	**104**	**130**	**135**	**149**	**156**	**162**	**166**	**1.0**
Japan	66	78	81	93	99	104	106	1.3
Australasia	38	52	53	56	57	58	60	0.6
Total Industrialized	**939**	**951**	**943**	**1,021**	**1,071**	**1,109**	**1,166**	**1.0**
EE/FSU								
Former Soviet Union	333	160	168	179	176	172	163	-0.1
Eastern Europe	189	127	113	113	110	107	100	-0.5
Total EE/FSU	**522**	**287**	**280**	**292**	**287**	**279**	**263**	**-0.3**
Developing Countries								
Developing Asia	**704**	**870**	**773**	**1,070**	**1,349**	**1,653**	**2,018**	**4.7**
China	514	600	495	698	923	1,169	1,452	5.3
India	101	148	156	200	227	252	295	3.1
South Korea	21	33	36	45	51	58	63	2.8
Other Asia	67	88	87	127	148	173	207	4.2
Middle East	**20**	**30**	**29**	**33**	**41**	**46**	**50**	**2.7**
Turkey	16	23	21	25	29	32	35	2.4
Other Middle East	4	7	7	8	12	14	15	3.5
Africa	**74**	**93**	**90**	**104**	**111**	**125**	**136**	**2.0**
Central and South America	**15**	**23**	**22**	**27**	**31**	**35**	**40**	**2.8**
Brazil	9	14	13	16	20	22	26	3.2
Other Central/South America	5	9	9	12	12	13	14	2.3
Total Developing	**812**	**1,017**	**914**	**1,234**	**1,532**	**1,859**	**2,245**	**4.4**
Total World	**2,274**	**2,254**	**2,137**	**2,547**	**2,889**	**3,246**	**3,674**	**2.6**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.
Notes: EE/FSU = Eastern Europe/Former Soviet Union.
Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table B19; and World Energy Projection System (2002).

Table B14. World Nuclear Generating Capacity by Region and Country, High Economic Growth Case, 1999-2020
(Megawatts)

Region/Country	History		Projections			
	1999	2000	2005	2010	2015	2020
Industrialized Countries						
North America	**108,776**	**108,867**	**112,656**	**110,404**	**104,897**	**106,087**
United States	97,470	97,509	97,700	95,448	89,941	89,131
Canada	9,998	9,998	13,596	13,596	13,596	14,596
Mexico	1,308	1,360	1,360	1,360	1,360	2,360
Industrialized Asia	**43,691**	**43,491**	**46,681**	**48,705**	**63,768**	**68,818**
Japan	43,691	43,491	46,681	48,705	63,768	68,818
Western Europe	**125,991**	**125,726**	**125,480**	**123,997**	**124,424**	**126,643**
Belgium	5,712	5,712	5,712	5,712	5,712	5,712
Finland	2,656	2,656	2,656	3,656	3,656	4,656
France	63,103	63,153	63,153	62,920	64,370	64,370
Germany	21,122	21,122	21,122	20,142	18,975	18,735
Italy	0	0	0	0	0	1,000
Netherlands	449	449	449	449	0	0
Spain	7,470	7,512	7,512	7,512	8,512	7,913
Sweden	9,432	9,432	9,432	9,432	9,432	7,507
Switzerland	3,079	3,192	3,192	3,192	3,192	4,392
United Kingdom	12,968	12,498	12,252	10,982	10,575	12,358
Total Industrialized	**278,458**	**278,084**	**284,817**	**283,106**	**293,089**	**301,548**
EE/FSU						
Eastern Europe	**10,605**	**10,675**	**12,508**	**11,934**	**11,098**	**13,039**
Bulgaria	3,538	3,538	3,538	2,722	1,906	2,859
Czech Republic	1,648	1,648	3,481	3,481	3,481	3,481
Hungary	1,729	1,755	1,755	1,755	1,755	2,355
Romania	650	650	650	1,300	1,300	1,300
Slovakia	2,408	2,408	2,408	2,000	1,980	2,368
Slovenia	632	676	676	676	676	676
Former Soviet Union	**34,704**	**33,796**	**36,652**	**38,597**	**40,560**	**42,762**
Armenia	376	376	376	376	376	0
Kazakhstan	0	0	0	0	0	600
Lithuania	2,370	2,370	2,370	1,185	1,000	1,000
Russia	19,843	19,843	22,699	23,929	26,077	26,155
Ukraine	12,115	11,207	11,207	13,107	13,107	15,007
Total EE/FSU	**45,309**	**44,471**	**49,160**	**50,531**	**51,658**	**55,801**

See notes at end of table.

Table B14. World Nuclear Generating Capacity by Region and Country, High Economic Growth Case, 1999-2020 (Continued)
(Megawatts)

Region/Country	History		Projections			
	1999	2000	2005	2010	2015	2020
Developing Countries						
Developing Asia	**22,063**	**22,777**	**32,219**	**43,369**	**57,663**	**69,849**
China	2,167	2,177	7,597	11,597	18,617	20,607
India	1,897	2,301	2,503	4,273	8,253	9,253
Korea, North	0	0	0	0	950	1,900
Korea, South	12,990	12,990	16,810	19,660	21,404	26,175
Pakistan	125	425	425	425	1,025	900
Taiwan	4,884	4,884	4,884	7,414	7,414	9,414
Thailand	0	0	0	0	0	600
Vietnam	0	0	0	0	0	1,000
Central and South America	**1,561**	**2,790**	**2,790**	**4,019**	**4,019**	**5,109**
Argentina	935	935	935	935	935	1,025
Brazil	626	1,855	1,855	3,084	3,084	4,084
Middle East	**0**	**0**	**1,073**	**2,146**	**2,586**	**4,626**
Israel	0	0	0	0	0	600
Iran	0	0	1,073	2,146	2,586	3,026
Turkey	0	0	0	0	0	1,000
Africa	**1,842**	**1,800**	**1,800**	**2,060**	**2,320**	**3,440**
Egypt	0	0	0	0	0	600
South Africa	1,842	1,800	1,800	2,060	2,320	2,840
Total Developing	**25,466**	**27,367**	**37,882**	**51,594**	**66,588**	**83,024**
Total World	**349,233**	**349,922**	**371,859**	**385,231**	**411,335**	**440,373**

Sources: **History:** International Atomic Energy Agency, *Nuclear Power Reactors in the World 2000* (Vienna, Austria, April 2001). **Projections:** Energy Information Administration (EIA), *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table A9; and EIA, Office of Coal, Nuclear, Electric and Alternate Fuels, based on detailed assessments of country-specific nuclear power plants.

Table B15. World Total Energy Consumption in Oil-Equivalent Units by Region, High Economic Growth Case, 1990-2020
(Million Tons Oil Equivalent)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**2,522**	**2,841**	**2,916**	**3,324**	**3,664**	**3,987**	**4,315**	**1.9**
United States[a]	2,121	2,383	2,446	2,749	3,001	3,243	3,484	1.7
Canada	275	305	316	362	396	423	448	1.7
Mexico	126	153	155	214	268	321	384	4.4
Western Europe	**1,508**	**1,659**	**1,664**	**1,861**	**1,971**	**2,080**	**2,218**	**1.4**
United Kingdom	234	251	250	279	298	318	337	1.4
France	222	256	258	293	314	332	359	1.6
Germany	373	357	352	401	421	438	462	1.3
Italy	176	201	203	232	249	266	282	1.6
Netherlands	85	96	97	107	112	118	124	1.2
Other Western Europe	419	498	504	549	577	608	655	1.3
Industrialized Asia	**574**	**695**	**704**	**781**	**829**	**881**	**934**	**1.4**
Japan	452	541	547	605	637	674	710	1.2
Australasia	122	153	157	176	192	207	225	1.7
Total Industrialized	**4,604**	**5,194**	**5,284**	**5,966**	**6,464**	**6,948**	**7,467**	**1.7**
EE/FSU								
Former Soviet Union	1,529	975	988	1,165	1,322	1,545	1,757	2.8
Eastern Europe	393	299	283	324	374	443	505	2.8
Total EE/FSU	**1,923**	**1,274**	**1,271**	**1,489**	**1,696**	**1,988**	**2,263**	**2.8**
Developing Countries								
Developing Asia	**1,286**	**1,837**	**1,788**	**2,618**	**3,402**	**4,352**	**5,428**	**5.4**
China	681	890	803	1,153	1,549	2,030	2,590	5.7
India	196	293	307	414	515	641	772	4.5
South Korea	92	173	185	246	284	340	395	3.7
Other Asia	317	481	492	805	1,054	1,341	1,671	6.0
Middle East	**330**	**481**	**487**	**599**	**760**	**940**	**1,156**	**4.2**
Turkey	50	76	74	93	115	139	168	4.0
Other Middle East	280	405	413	506	645	801	988	4.2
Africa	**235**	**292**	**297**	**385**	**453**	**549**	**645**	**3.8**
Central and South America	**346**	**489**	**498**	**667**	**869**	**1,126**	**1,387**	**5.0**
Brazil	142	208	215	258	324	399	479	3.9
Other Central/South America	204	282	283	409	545	727	908	5.7
Total Developing	**2,197**	**3,100**	**3,069**	**4,269**	**5,484**	**6,966**	**8,615**	**5.0**
Total World	**8,724**	**9,568**	**9,623**	**11,724**	**13,644**	**15,902**	**18,345**	**3.1**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.
Notes: EE/FSU = Eastern Europe/Former Soviet Union.
Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table B1; and World Energy Projection System (2002).

Appendix C

Low Economic Growth Case Projections:

World Energy Consumption
Gross Domestic Product
Carbon Dioxide Emissions
Nuclear Power Capacity

Table C1. World Total Energy Consumption by Region, Low Economic Growth Case, 1990-2020
(Quadrillion Btu)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**100.1**	**112.7**	**115.7**	**127.7**	**135.9**	**143.5**	**149.8**	**1.2**
United States[a]	84.2	94.6	97.0	106.6	113.0	119.2	124.1	1.2
Canada	10.9	12.1	12.5	13.5	14.0	14.3	14.5	0.7
Mexico	5.0	6.1	6.1	7.6	8.8	9.9	11.2	2.9
Western Europe	**59.8**	**65.8**	**66.0**	**69.5**	**71.1**	**72.6**	**74.3**	**0.6**
United Kingdom	9.3	9.9	9.9	10.5	10.8	11.1	11.4	0.7
France	8.8	10.2	10.3	10.9	11.2	11.4	11.7	0.6
Germany	14.8	14.2	14.0	14.8	15.1	15.3	15.5	0.5
Italy	7.0	8.0	8.0	8.5	8.7	8.9	9.1	0.6
Netherlands	3.4	3.8	3.8	4.0	4.1	4.2	4.3	0.5
Other Western Europe	16.6	19.8	20.0	20.8	21.2	21.6	22.3	0.5
Industrialized Asia	**22.8**	**27.6**	**27.9**	**28.3**	**28.8**	**29.4**	**30.0**	**0.3**
Japan	17.9	21.5	21.7	21.8	22.0	22.4	22.7	0.2
Australasia	4.8	6.1	6.2	6.6	6.8	7.0	7.3	0.8
Total Industrialized	**182.7**	**206.1**	**209.7**	**225.5**	**235.8**	**245.5**	**254.1**	**0.9**
EE/FSU								
Former Soviet Union	60.7	38.7	39.2	41.4	43.2	46.5	48.7	1.0
Eastern Europe	15.6	11.9	11.2	11.9	12.7	13.5	14.2	1.1
Total EE/FSU	**76.3**	**50.6**	**50.4**	**53.3**	**55.8**	**60.1**	**62.9**	**1.1**
Developing Countries								
Developing Asia	**51.0**	**72.9**	**70.9**	**87.6**	**100.8**	**114.0**	**126.7**	**2.8**
China	27.0	35.3	31.9	38.3	44.4	50.2	55.7	2.7
India	7.8	11.6	12.2	14.6	16.6	18.8	20.9	2.6
South Korea	3.7	6.9	7.3	8.6	9.3	10.3	11.1	2.0
Other Asia	12.6	19.1	19.5	26.1	30.5	34.8	39.0	3.4
Middle East	**13.1**	**19.1**	**19.3**	**21.3**	**24.1**	**27.0**	**30.2**	**2.1**
Turkey	2.0	3.0	3.0	3.3	3.7	4.1	4.5	2.0
Other Middle East	11.1	16.1	16.4	18.0	20.4	22.9	25.7	2.2
Africa	**9.3**	**11.6**	**11.8**	**13.4**	**14.5**	**15.8**	**16.9**	**1.7**
Central and South America	**13.7**	**19.4**	**19.8**	**23.0**	**26.3**	**29.8**	**32.9**	**2.5**
Brazil	5.7	8.2	8.5	9.4	10.6	11.7	12.8	2.0
Other Central/South America	8.1	11.2	11.2	13.6	15.7	18.1	20.1	2.8
Total Developing	**87.2**	**123.0**	**121.8**	**145.2**	**165.6**	**186.6**	**206.7**	**2.6**
Total World	**346.2**	**379.7**	**381.9**	**424.1**	**457.3**	**492.1**	**523.6**	**1.5**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. 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 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table B1; and World Energy Projection System (2002).

Table C2. World Total Energy Consumption by Region and Fuel, Low Economic Growth Case, 1990-2020
(Quadrillion Btu)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America								
Oil	40.4	44.6	45.8	49.9	53.8	57.6	60.7	1.4
Natural Gas	22.7	26.2	26.8	30.9	33.6	36.6	38.8	1.8
Coal	20.5	23.5	23.5	25.8	27.0	27.5	28.2	0.9
Nuclear	7.0	8.0	8.6	9.2	9.0	8.5	8.4	-0.1
Other	9.5	10.7	11.4	11.9	12.6	13.3	13.7	0.9
Total	**100.1**	**112.7**	**115.7**	**127.7**	**135.9**	**143.5**	**149.8**	**1.2**
Western Europe								
Oil	25.8	29.1	28.7	29.8	29.9	29.9	29.6	0.1
Natural Gas	9.7	13.6	14.3	17.5	19.3	21.3	24.4	2.6
Coal	12.4	8.8	8.4	7.5	7.1	6.7	6.0	-1.6
Nuclear	7.4	8.8	8.9	8.4	8.2	7.7	6.8	-1.2
Other	4.5	5.4	5.6	6.3	6.7	7.1	7.5	1.4
Total	**59.8**	**65.8**	**66.0**	**69.5**	**71.1**	**72.6**	**74.3**	**0.6**
Industrialized Asia								
Oil	12.5	13.7	13.9	14.1	14.4	14.4	14.4	0.2
Natural Gas	2.5	3.6	3.8	3.9	4.0	4.3	4.8	1.1
Coal	4.2	5.3	5.4	5.5	5.5	5.5	5.4	0.0
Nuclear	2.0	3.2	3.2	3.1	3.2	3.4	3.5	0.4
Other	1.6	1.7	1.7	1.7	1.7	1.8	1.9	0.6
Total	**22.8**	**27.6**	**27.9**	**28.3**	**28.8**	**29.4**	**30.0**	**0.3**
Total Industrialized								
Oil	78.7	87.4	88.4	93.8	98.1	101.9	104.7	0.8
Natural Gas	35.0	43.5	44.8	52.4	56.8	62.2	68.0	2.0
Coal	37.1	37.5	37.3	38.7	39.5	39.7	39.6	0.3
Nuclear	16.3	20.0	20.6	20.7	20.4	19.6	18.7	-0.5
Other	15.6	17.9	18.6	19.9	21.1	22.2	23.1	1.0
Total	**182.7**	**206.1**	**209.7**	**225.5**	**235.8**	**245.5**	**254.1**	**0.9**
EE/FSU								
Oil	21.0	10.9	10.8	13.2	14.7	16.8	18.1	2.5
Natural Gas	28.8	22.7	22.9	23.6	25.7	28.8	31.6	1.6
Coal	20.8	11.4	11.1	10.5	9.5	8.4	7.3	-2.0
Nuclear	2.9	2.7	2.7	3.0	2.7	2.7	2.4	-0.7
Other	2.8	3.0	3.0	3.0	3.1	3.3	3.5	0.7
Total	**76.3**	**50.6**	**50.4**	**53.3**	**55.8**	**60.1**	**62.9**	**1.1**
Developing Countries								
Developing Asia								
Oil	16.0	26.7	27.7	32.7	38.1	44.2	49.5	2.8
Natural Gas	3.2	6.0	6.4	10.7	13.3	16.3	19.2	5.4
Coal	27.7	34.5	30.7	35.9	39.7	42.6	45.8	1.9
Nuclear	0.9	1.5	1.6	2.2	2.6	3.0	3.5	3.8
Other	3.2	4.3	4.6	6.2	7.1	8.0	8.6	3.0
Total	**51.0**	**72.9**	**70.9**	**87.6**	**100.8**	**114.0**	**126.7**	**2.8**

See notes at end of table.

Table C2. World Total Energy Consumption by Region and Fuel, Low Economic Growth Case, 1990-2020 (Continued)
(Quadrillion Btu)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Developing Countries (Continued)								
Middle East								
Oil	8.1	10.4	10.5	11.4	12.0	13.0	14.2	1.4
Natural Gas	3.9	6.9	7.1	8.0	9.9	11.5	13.3	3.0
Coal	0.8	1.2	1.1	1.1	1.3	1.3	1.3	0.7
Nuclear	0.0	0.0	0.0	0.0	0.1	0.1	0.1	—
Other	0.4	0.6	0.5	0.7	0.8	1.1	1.3	4.5
Total	**13.1**	**19.1**	**19.3**	**21.3**	**24.1**	**27.0**	**30.2**	**2.2**
Africa								
Oil	4.2	5.1	5.2	6.5	7.4	8.2	9.1	2.7
Natural Gas	1.5	2.0	2.1	2.4	2.5	2.9	3.1	1.8
Coal	3.0	3.7	3.6	3.7	3.6	3.6	3.6	0.0
Nuclear	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0
Other	0.6	0.7	0.7	0.8	0.8	0.9	1.0	1.6
Total	**9.3**	**11.6**	**11.8**	**13.4**	**14.5**	**15.8**	**16.9**	**1.7**
Central and South America								
Oil	7.0	9.4	9.5	10.8	12.0	12.8	13.8	1.8
Natural Gas	2.2	3.4	3.5	4.9	7.2	10.1	12.1	6.0
Coal	0.6	0.9	0.9	1.0	1.0	0.9	1.0	0.4
Nuclear	0.1	0.1	0.1	0.2	0.2	0.1	0.2	2.3
Other	3.9	5.6	5.7	6.1	5.9	5.9	5.8	0.1
Total	**13.7**	**19.4**	**19.8**	**23.0**	**26.3**	**29.8**	**32.9**	**2.5**
Total Developing Countries								
Oil	35.2	51.5	52.9	61.3	69.6	78.2	86.6	2.4
Natural Gas	10.8	18.3	19.2	26.0	32.9	40.8	47.7	4.4
Coal	32.1	40.3	36.3	41.7	45.6	48.4	51.7	1.7
Nuclear	1.1	1.7	1.9	2.5	2.9	3.3	4.0	3.7
Other	8.0	11.1	11.5	13.8	14.6	15.8	16.6	1.8
Total	**87.2**	**123.0**	**121.8**	**145.2**	**165.6**	**186.6**	**206.7**	**2.6**
Total World								
Oil	134.9	149.8	152.2	168.4	182.4	196.9	209.4	1.5
Natural Gas	74.5	84.5	86.9	102.0	115.4	131.7	147.3	2.5
Coal	90.0	89.3	84.8	90.9	94.6	96.5	98.7	0.7
Nuclear	20.4	24.4	25.3	26.1	26.1	25.6	25.1	0.0
Other	26.5	32.0	33.1	36.6	38.8	41.3	43.2	1.3
Total	**346.2**	**379.7**	**381.9**	**424.1**	**457.3**	**492.1**	**523.6**	**1.5**

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 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table B1; and World Energy Projection System (2002).

Table C3. World Gross Domestic Product (GDP) by Region, Low Economic Growth Case, 1990-2020
(Billion 1997 Dollars)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**7,723**	**9,760**	**10,165**	**11,973**	**13,310**	**14,527**	**15,729**	**2.1**
United States[a]	6,836	8,675	9,029	10,630	11,788	12,827	13,835	2.1
Canada	555	665	699	801	870	912	936	1.4
Mexico	332	421	437	542	652	788	958	3.8
Western Europe	**7,597**	**8,731**	**8,944**	**9,854**	**10,518**	**11,164**	**11,804**	**1.3**
United Kingdom	1,146	1,353	1,384	1,558	1,677	1,826	1,955	1.7
France	1,299	1,455	1,499	1,664	1,789	1,873	1,949	1.3
Germany	1,879	2,156	2,187	2,378	2,514	2,649	2,786	1.2
Italy	1,079	1,188	1,207	1,307	1,386	1,463	1,536	1.2
Netherlands	317	392	407	449	481	513	544	1.4
Other Western Europe	1,877	2,187	2,260	2,499	2,670	2,841	3,035	1.4
Industrialized Asia	**4,054**	**4,765**	**4,821**	**4,912**	**5,083**	**5,317**	**5,514**	**0.6**
Japan	3,673	4,271	4,304	4,340	4,468	4,655	4,797	0.5
Australasia	381	494	516	572	615	663	717	1.6
Total Industrialized	**19,374**	**23,256**	**23,930**	**26,739**	**28,910**	**31,009**	**33,048**	**1.5**
EE/FSU								
Former Soviet Union	1,009	545	569	647	723	882	994	2.7
Eastern Europe	348	358	363	444	517	597	675	3.0
Total EE/FSU	**1,357**	**903**	**932**	**1,091**	**1,240**	**1,479**	**1,669**	**2.8**
Developing Countries								
Developing Asia	**1,739**	**2,975**	**3,165**	**4,037**	**4,934**	**5,898**	**6,954**	**3.8**
China	427	968	1,037	1,343	1,669	1,988	2,338	3.9
India	268	445	473	613	752	917	1,112	4.2
South Korea	297	445	493	599	718	852	1,002	3.4
Other Asia	748	1,118	1,162	1,482	1,795	2,141	2,502	3.7
Middle East	**379**	**580**	**577**	**678**	**790**	**933**	**1,108**	**3.2**
Turkey	140	196	186	220	257	301	353	3.1
Other Middle East	239	384	391	458	533	631	754	3.2
Africa	**405**	**485**	**499**	**596**	**681**	**764**	**848**	**2.6**
Central and South America	**1,136**	**1,467**	**1,452**	**1,740**	**2,020**	**2,316**	**2,643**	**2.9**
Brazil	674	810	816	982	1,149	1,320	1,510	3.0
Other Central/South America	462	657	636	758	871	996	1,132	2.8
Total Developing	**3,660**	**5,507**	**5,693**	**7,051**	**8,425**	**9,910**	**11,553**	**3.4**
Total World	**24,392**	**29,665**	**30,555**	**34,881**	**38,576**	**42,398**	**46,269**	**2.0**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

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

Sources: DRI-WEFA, *World Economic Outlook*, Vol. 1 (Lexington, MA, 3rd Quarter 2001); Energy Information Administration (EIA), *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table B20; and EIA, World Energy Projection System (2002).

Table C4. World Oil Consumption by Region, Low Economic Growth Case, 1990-2020
(Million Barrels per Day)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**20.4**	**22.7**	**23.4**	**25.5**	**27.5**	**29.4**	**30.9**	**1.3**
United States[a]	17.0	18.9	19.5	21.1	22.6	24.0	25.0	1.2
Canada	1.7	1.9	1.9	2.1	2.1	2.1	2.1	0.4
Mexico	1.7	1.9	2.0	2.4	2.7	3.2	3.8	3.1
Western Europe	**12.5**	**14.1**	**13.9**	**14.4**	**14.5**	**14.5**	**14.4**	**0.1**
United Kingdom	1.8	1.8	1.7	2.0	2.0	2.0	2.1	0.9
France	1.8	2.0	2.0	2.1	2.1	2.1	2.1	0.1
Germany	2.7	2.9	2.8	3.0	3.0	2.9	2.9	0.1
Italy	1.9	2.1	2.0	2.0	2.0	1.9	1.9	-0.2
Netherlands	0.7	0.8	0.8	0.8	0.9	0.9	0.9	0.3
Other Western Europe	3.6	4.5	4.5	4.5	4.5	4.5	4.5	0.0
Industrialized Asia	**6.2**	**6.8**	**6.9**	**7.0**	**7.1**	**7.1**	**7.1**	**0.2**
Japan	5.1	5.5	5.6	5.6	5.6	5.6	5.5	-0.1
Australasia	1.0	1.3	1.3	1.4	1.5	1.6	1.7	1.2
Total Industrialized	**39.0**	**43.6**	**44.2**	**46.9**	**49.1**	**51.0**	**52.4**	**0.8**
EE/FSU								
Former Soviet Union	8.4	3.8	3.7	4.7	5.3	6.3	6.8	2.9
Eastern Europe	1.6	1.4	1.5	1.6	1.7	1.8	1.8	1.2
Total EE/FSU	**10.0**	**5.2**	**5.2**	**6.3**	**7.1**	**8.1**	**8.6**	**2.5**
Developing Countries								
Developing Asia	**7.6**	**12.8**	**13.3**	**15.7**	**18.3**	**21.2**	**23.8**	**2.8**
China	2.3	4.1	4.3	4.7	5.5	6.3	7.0	2.3
India	1.2	1.8	1.9	2.4	2.9	3.6	4.1	3.6
South Korea	1.0	2.0	2.0	2.2	2.4	2.5	2.6	1.2
Other Asia	3.1	4.9	5.0	6.4	7.5	8.9	10.1	3.4
Middle East	**3.9**	**5.0**	**5.0**	**5.5**	**5.8**	**6.2**	**6.8**	**1.4**
Turkey	0.5	0.6	0.6	0.8	0.8	0.9	1.0	2.4
Other Middle East	3.4	4.3	4.4	4.7	4.9	5.3	5.8	1.3
Africa	**2.1**	**2.5**	**2.5**	**3.1**	**3.6**	**4.0**	**4.4**	**2.7**
Central and South America	**3.4**	**4.6**	**4.7**	**5.3**	**5.9**	**6.2**	**6.7**	**1.8**
Brazil	1.3	1.9	2.0	2.1	2.4	2.6	3.0	2.0
Other Central/South America	2.1	2.7	2.7	3.1	3.5	3.6	3.8	1.6
Total Developing	**17.0**	**24.8**	**25.5**	**29.6**	**33.5**	**37.7**	**41.7**	**2.4**
Total World	**66.0**	**73.6**	**74.9**	**82.8**	**89.6**	**96.7**	**102.7**	**1.5**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. 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 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table B21; and World Energy Projection System (2002).

Table C5. World Natural Gas Consumption by Region, Low Economic Growth Case, 1990-2020
(Trillion Cubic Feet)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**22.0**	**25.4**	**26.1**	**30.1**	**32.7**	**35.6**	**37.8**	**1.8**
United States[a]	18.7	21.3	21.7	25.2	27.4	30.0	32.0	1.9
Canada	2.4	2.9	3.1	3.3	3.4	3.6	3.7	0.9
Mexico	0.9	1.3	1.3	1.7	1.9	2.1	2.1	2.4
Western Europe	**10.1**	**13.4**	**14.0**	**17.1**	**18.8**	**20.7**	**23.7**	**2.5**
United Kingdom	2.1	3.1	3.3	3.7	4.1	4.5	5.1	2.2
France	1.0	1.3	1.3	1.8	2.0	2.2	2.6	3.2
Germany	2.7	3.0	3.0	3.9	4.2	4.5	5.3	2.7
Italy	1.7	2.2	2.4	2.8	3.0	3.3	3.5	1.8
Netherlands	1.5	1.8	1.7	1.9	2.0	2.1	2.1	1.1
Other Western Europe	1.2	2.0	2.3	3.1	3.5	4.1	4.9	3.8
Industrialized Asia	**2.6**	**3.5**	**3.6**	**3.8**	**3.8**	**4.1**	**4.6**	**1.1**
Japan	1.9	2.5	2.6	2.7	2.6	2.8	3.2	0.9
Australasia	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.7
Total Industrialized	**34.8**	**42.3**	**43.7**	**51.0**	**55.3**	**60.5**	**66.1**	**2.0**
EE/FSU								
Former Soviet Union	25.0	19.9	20.1	20.4	21.6	23.6	25.6	1.2
Eastern Europe	3.1	2.5	2.4	2.9	3.8	4.7	5.5	4.0
Total EE/FSU	**28.1**	**22.4**	**22.5**	**23.3**	**25.4**	**28.4**	**31.1**	**1.6**
Developing Countries								
Developing Asia	**3.0**	**5.6**	**6.0**	**10.0**	**12.4**	**15.1**	**17.8**	**5.3**
China	0.5	0.8	0.9	1.6	2.3	3.3	4.3	7.9
India	0.4	0.8	0.8	1.1	1.4	1.9	2.2	5.1
South Korea	0.1	0.5	0.6	1.1	1.2	1.6	1.9	5.8
Other Asia	1.9	3.6	3.8	6.2	7.5	8.4	9.5	4.4
Middle East	**3.7**	**6.6**	**6.8**	**7.6**	**9.4**	**11.0**	**12.6**	**3.0**
Turkey	0.1	0.4	0.4	0.5	0.6	0.8	0.9	3.6
Other Middle East	3.6	6.2	6.3	7.2	8.8	10.2	11.7	1.8
Africa	**1.4**	**1.8**	**2.0**	**2.2**	**2.4**	**2.7**	**2.9**	**1.8**
Central and South America	**2.0**	**3.1**	**3.2**	**4.5**	**6.6**	**9.2**	**11.1**	**6.0**
Brazil	0.1	0.2	0.2	0.6	1.2	2.0	2.4	11.8
Other Central/South America	1.9	2.9	3.0	4.0	5.4	7.3	8.7	5.2
Total Developing	**10.1**	**17.2**	**18.0**	**24.4**	**30.8**	**38.0**	**44.5**	**4.4**
Total World	**72.9**	**81.9**	**84.2**	**98.6**	**111.4**	**126.9**	**141.7**	**2.5**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. 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 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table B13; and World Energy Projection System (2002).

Table C6. World Coal Consumption by Region, Low Economic Growth Case, 1990-2020
(Million Short Tons)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**959**	**1,121**	**1,122**	**1,254**	**1,326**	**1,357**	**1,400**	**1.1**
United States[a]	895	1,040	1,045	1,169	1,235	1,262	1,303	1.1
Canada	55	66	63	65	69	71	72	0.6
Mexico	9	15	13	20	22	24	26	3.3
Western Europe	**894**	**566**	**546**	**483**	**462**	**439**	**399**	**-1.5**
United Kingdom	119	70	65	59	56	50	40	-2.2
France	35	29	26	22	15	15	12	-3.5
Germany	528	269	258	228	225	217	201	-1.2
Italy	23	19	19	16	16	14	13	-1.8
Netherlands	15	16	14	12	8	8	6	-3.7
Other Western Europe	173	164	165	145	142	134	126	-1.2
Industrialized Asia	**231**	**287**	**295**	**298**	**297**	**296**	**291**	**-0.1**
Japan	125	144	149	155	158	160	157	0.2
Australasia	106	142	145	143	139	136	134	-0.4
Total Industrialized	**2,084**	**1,974**	**1,963**	**2,035**	**2,085**	**2,091**	**2,091**	**0.3**
EE/FSU								
Former Soviet Union	848	396	414	395	358	322	281	-1.8
Eastern Europe	527	414	363	339	303	265	229	-2.2
Total EE/FSU	**1,375**	**810**	**778**	**734**	**662**	**588**	**510**	**-2.0**
Developing Countries								
Developing Asia	**1,583**	**1,903**	**1,686**	**1,975**	**2,183**	**2,338**	**2,521**	**1.9**
China	1,124	1,300	1,075	1,269	1,449	1,582	1,710	2.2
India	242	333	348	396	410	416	450	1.2
South Korea	42	60	65	72	77	81	82	1.1
Other Asia	175	210	197	238	247	259	279	1.7
Middle East	**66**	**99**	**96**	**97**	**109**	**110**	**110**	**0.7**
Turkey	60	86	84	86	92	92	92	0.4
Other Middle East	6	12	12	11	17	18	18	1.9
Africa	**152**	**181**	**177**	**179**	**176**	**178**	**177**	**0.0**
Central and South America	**26**	**42**	**41**	**44**	**44**	**43**	**44**	**0.4**
Brazil	17	28	27	30	33	33	35	1.3
Other Central/South America	9	15	14	15	11	10	9	-2.1
Total Developing	**1,827**	**2,226**	**2,000**	**2,295**	**2,512**	**2,670**	**2,852**	**1.7**
Total World	**5,287**	**5,009**	**4,740**	**5,065**	**5,259**	**5,349**	**5,453**	**0.7**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding. 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 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table B16; and World Energy Projection System (2002).

Table C7. World Nuclear Energy Consumption by Region, Low Economic Growth Case, 1990-2020
(Billion Kilowatthours)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**649**	**750**	**808**	**858**	**834**	**793**	**785**	**-0.1**
United States[a]	577	674	728	759	737	697	691	-0.2
Canada	69	68	70	90	90	88	87	1.0
Mexico	3	9	10	9	8	8	7	-1.1
Western Europe	**703**	**836**	**846**	**808**	**785**	**739**	**660**	**-1.2**
United Kingdom	59	95	91	66	58	49	29	-5.3
France	298	369	375	383	383	379	380	0.1
Germany	145	154	161	149	139	129	95	-2.5
Italy	0	0	0	0	0	0	0	—
Netherlands	3	4	4	4	0	0	0	-100.0
Other Western Europe	198	215	215	206	206	181	156	-1.5
Industrialized Asia	**192**	**316**	**309**	**302**	**316**	**330**	**338**	**0.4**
Japan	192	316	309	302	316	330	338	0.4
Australasia	0	0	0	0	0	0	0	0.0
Total Industrialized	**1,544**	**1,902**	**1,962**	**1,967**	**1,936**	**1,861**	**1,784**	**-0.5**
EE/FSU								
Former Soviet Union	201	183	190	194	183	177	145	-1.3
Eastern Europe	54	61	60	77	66	66	70	0.8
Total EE/FSU	**256**	**244**	**250**	**270**	**249**	**243**	**216**	**-0.7**
Developing Countries								
Developing Asia	**88**	**145**	**160**	**213**	**256**	**291**	**346**	**3.7**
China	0	13	14	46	60	66	86	9.0
India	6	11	11	15	23	26	37	5.8
South Korea	50	85	98	113	113	135	154	2.2
Other Asia	32	36	37	40	60	65	68	3.0
Middle East	**0**	**0**	**0**	**0**	**5**	**11**	**11**	**—**
Turkey	0	0	0	0	0	0	0	—
Other Middle East	0	0	0	0	5	11	11	—
Africa	**8**	**14**	**13**	**12**	**12**	**12**	**13**	**0.0**
Central and South America	**9**	**10**	**11**	**15**	**15**	**12**	**17**	**2.3**
Brazil	2	3	4	10	10	10	15	6.9
Other Central/South America	7	7	7	5	5	2	2	-6.4
Total Developing	**105**	**169**	**184**	**240**	**288**	**326**	**388**	**3.6**
Total World	**1,905**	**2,315**	**2,396**	**2,478**	**2,473**	**2,430**	**2,388**	**0.0**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table B8; and World Energy Projection System (2002).

Table C8. World Consumption of Hydroelectricity and Other Renewable Energy by Region, Low Economic Growth Case, 1990-2020
(Quadrillion Btu)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**9.5**	**10.7**	**11.4**	**11.9**	**12.6**	**13.3**	**13.7**	**0.9**
United States[a]	6.1	6.9	7.3	7.8	8.1	8.7	9.0	1.0
Canada	3.1	3.5	3.6	3.6	3.8	3.9	3.9	0.4
Mexico	0.3	0.4	0.4	0.5	0.7	0.7	0.8	2.5
Western Europe	**4.5**	**5.4**	**5.6**	**6.3**	**6.7**	**7.1**	**7.5**	**1.4**
United Kingdom	0.1	0.1	0.1	0.3	0.3	0.4	0.4	5.2
France	0.6	0.7	0.8	0.2	0.3	0.3	0.3	-4.0
Germany	0.3	0.3	0.4	0.6	0.7	0.8	0.9	4.4
Italy	0.4	0.5	0.6	1.1	1.1	1.2	1.2	3.6
Netherlands	0.0	0.0	0.0	0.3	0.3	0.3	0.4	10.0
Other Western Europe	3.2	3.7	3.7	3.9	4.0	4.1	4.3	0.7
Industrialized Asia	**1.6**	**1.7**	**1.7**	**1.7**	**1.7**	**1.8**	**1.9**	**0.6**
Japan	1.1	1.2	1.2	1.2	1.1	1.3	1.3	0.5
Australasia	0.4	0.5	0.5	0.5	0.6	0.6	0.6	0.8
Total Industrialized	**15.6**	**17.9**	**18.6**	**19.9**	**21.1**	**22.2**	**23.1**	**1.0**
EE/FSU								
Former Soviet Union	2.4	2.3	2.3	2.3	2.3	2.3	2.4	0.0
Eastern Europe	0.4	0.6	0.6	0.6	0.8	1.0	1.1	2.8
Total EE/FSU	**2.8**	**3.0**	**3.0**	**3.0**	**3.1**	**3.3**	**3.5**	**0.7**
Developing Countries								
Developing Asia	**3.2**	**4.3**	**4.6**	**6.2**	**7.1**	**8.0**	**8.6**	**3.0**
China	1.3	2.1	2.3	3.0	3.4	3.9	4.3	3.0
India	0.7	0.8	0.9	1.1	1.2	1.3	1.4	2.3
South Korea	0.0	0.0	0.0	0.1	0.1	0.1	0.2	7.1
Other Asia	1.1	1.3	1.4	2.0	2.3	2.6	2.6	3.2
Middle East	**0.4**	**0.6**	**0.5**	**0.7**	**0.8**	**1.1**	**1.3**	**4.5**
Turkey	0.2	0.4	0.4	0.4	0.4	0.4	0.5	1.4
Other Middle East	0.1	0.2	0.2	0.3	0.4	0.6	0.8	8.0
Africa	**0.6**	**0.7**	**0.7**	**0.8**	**0.8**	**0.9**	**1.0**	**1.6**
Central and South America	**3.9**	**5.6**	**5.7**	**6.1**	**5.9**	**5.9**	**5.8**	**0.1**
Brazil	2.2	3.1	3.3	3.8	3.8	3.5	3.3	0.1
Other Central/South America	1.7	2.5	2.4	2.3	2.2	2.3	2.5	0.2
Total Developing	**8.0**	**11.1**	**11.5**	**13.8**	**14.6**	**15.8**	**16.6**	**1.8**
Total World	**26.5**	**32.0**	**33.1**	**36.6**	**38.8**	**41.3**	**43.2**	**1.3**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. 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 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table B1; and World Energy Projection System (2002).

Table C9. World Net Electricity Consumption by Region, Low Economic Growth Case, 1990-2020
(Billion Kilowatthours)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**3,362**	**4,046**	**3,904**	**4,533**	**4,939**	**5,331**	**5,696**	**1.8**
United States[a]	2,817	3,400	3,236	3,760	4,084	4,404	4,691	1.8
Canada	438	485	498	546	577	599	615	1.0
Mexico	107	162	171	227	277	329	390	4.0
Western Europe	**2,077**	**2,399**	**2,435**	**2,676**	**2,830**	**2,985**	**3,160**	**1.2**
United Kingdom	287	330	333	369	386	404	420	1.1
France	326	394	399	417	442	464	488	1.0
Germany	489	492	495	549	579	608	642	1.2
Italy	222	266	272	322	348	375	403	1.9
Netherlands	72	95	98	108	115	122	129	1.3
Other Western Europe	681	822	838	911	960	1,012	1,078	1.2
Industrialized Asia	**945**	**1,158**	**1,178**	**1,244**	**1,291**	**1,339**	**1,385**	**0.8**
Japan	765	932	947	983	1,017	1,053	1,085	0.6
Australasia	181	226	231	261	274	286	300	1.3
Total Industrialized	**6,385**	**7,604**	**7,517**	**8,453**	**9,060**	**9,656**	**10,240**	**1.5**
EE/FSU								
Former Soviet Union	1,488	1,068	1,075	1,113	1,167	1,264	1,329	1.0
Eastern Europe	418	390	377	411	440	475	504	1.4
Total EE/FSU	**1,906**	**1,459**	**1,452**	**1,523**	**1,607**	**1,739**	**1,833**	**1.1**
Developing Countries								
Developing Asia	**1,259**	**2,175**	**2,319**	**2,715**	**3,188**	**3,679**	**4,171**	**2.8**
China	551	1,013	1,084	1,202	1,447	1,695	1,952	2.8
India	257	396	424	493	566	649	730	2.6
South Korea	93	207	233	259	284	316	346	1.9
Other Asia	357	560	578	762	891	1,018	1,143	3.3
Middle East	**263**	**470**	**494**	**518**	**593**	**671**	**760**	**2.1**
Turkey	51	102	106	120	135	151	168	2.2
Other Middle East	213	368	388	399	458	521	591	2.0
Africa	**287**	**361**	**367**	**442**	**508**	**587**	**646**	**2.7**
Central and South America	**449**	**656**	**684**	**779**	**895**	**1,019**	**1,130**	**2.4**
Brazil	229	334	354	422	483	544	603	2.6
Other Central/South America	220	322	330	357	412	476	527	2.3
Total Developing	**2,258**	**3,663**	**3,863**	**4,455**	**5,184**	**5,956**	**6,707**	**2.7**
Total World	**10,549**	**12,725**	**12,833**	**14,431**	**15,851**	**17,351**	**18,780**	**1.8**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Electricity consumption equals generation plus imports minus exports minus distribution losses.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table B2; and World Energy Projection System (2002).

Table C10. World Carbon Dioxide Emissions by Region, Low Economic Growth Case, 1990-2020
(Million Metric Tons Carbon Equivalent)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**1,562**	**1,742**	**1,767**	**1,963**	**2,102**	**2,229**	**2,338**	**1.3**
United States[a]	1,352	1,495	1,517	1,680	1,795	1,897	1,980	1.3
Canada	126	146	150	157	163	168	170	0.6
Mexico	84	101	101	126	144	164	188	3.0
Western Europe	**930**	**947**	**940**	**980**	**996**	**1,014**	**1,036**	**0.5**
United Kingdom	164	154	151	164	169	174	178	0.8
France	102	110	109	115	117	120	122	0.6
Germany	271	237	230	237	240	242	247	0.3
Italy	112	122	121	127	129	130	132	0.4
Netherlands	58	66	64	65	65	66	66	0.1
Other Western Europe	223	260	264	271	276	283	292	0.5
Industrialized Asia	**357**	**412**	**422**	**430**	**435**	**440**	**445**	**0.3**
Japan	269	300	307	310	312	314	315	0.1
Australasia	88	112	115	120	123	126	130	1.0
Total Industrialized	**2,849**	**3,101**	**3,129**	**3,373**	**3,533**	**3,683**	**3,820**	**1.0**
EE/FSU								
Former Soviet Union	1,036	599	607	643	670	721	754	1.0
Eastern Europe	301	217	203	208	213	219	221	0.4
Total EE/FSU	**1,337**	**816**	**810**	**850**	**883**	**940**	**975**	**0.9**
Developing Countries								
Developing Asia	**1,053**	**1,435**	**1,361**	**1,645**	**1,876**	**2,100**	**2,321**	**2.6**
China	617	765	669	786	907	1,014	1,115	2.5
India	153	231	242	285	318	354	392	2.3
South Korea	61	101	107	125	136	147	156	1.8
Other Asia	223	338	343	449	515	585	658	3.1
Middle East	**231**	**325**	**330**	**359**	**402**	**444**	**491**	**1.9**
Turkey	35	50	50	56	62	68	74	1.9
Other Middle East	196	275	280	304	340	376	418	1.9
Africa	**179**	**216**	**218**	**246**	**265**	**285**	**304**	**1.6**
Central and South America	**178**	**246**	**249**	**294**	**349**	**405**	**454**	**2.9**
Brazil	62	87	88	100	120	141	161	2.9
Other Central/South America	116	159	162	194	230	264	292	2.9
Total Developing	**1,641**	**2,222**	**2,158**	**2,545**	**2,892**	**3,234**	**3,570**	**2.4**
Total World	**5,827**	**6,139**	**6,097**	**6,767**	**7,309**	**7,857**	**8,365**	**1.5**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. The U.S. numbers include carbon dioxide emissions attributable to renewable energy sources.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table B19; and World Energy Projection System (2002).

Table C11. World Carbon Dioxide Emissions from Oil Use by Region, Low Economic Growth Case, 1990-2020
(Million Metric Tons Carbon Equivalent)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**716**	**775**	**793**	**863**	**933**	**1,002**	**1,060**	**1.4**
United States[a]	590	635	650	699	754	805	841	1.2
Canada	61	66	68	72	74	74	74	0.4
Mexico	65	74	76	92	105	122	145	3.1
Western Europe	**474**	**525**	**517**	**536**	**539**	**538**	**533**	**0.1**
United Kingdom	66	65	63	72	73	75	75	0.9
France	67	72	72	74	76	75	74	0.1
Germany	103	107	104	109	109	108	107	0.1
Italy	74	78	74	76	75	73	72	-0.2
Netherlands	27	30	31	32	32	33	33	0.3
Other Western Europe	138	172	173	173	174	173	172	0.0
Industrialized Asia	**217**	**230**	**233**	**236**	**241**	**242**	**242**	**0.2**
Japan	179	183	185	185	187	185	181	-0.1
Australasia	38	46	48	51	54	57	61	1.2
Total Industrialized	**1,407**	**1,529**	**1,543**	**1,636**	**1,713**	**1,781**	**1,835**	**0.8**
EE/FSU								
Former Soviet Union	334	148	146	185	209	245	266	2.9
Eastern Europe	66	55	55	60	64	68	70	1.2
Total EE/FSU	**400**	**202**	**201**	**245**	**274**	**313**	**335**	**2.5**
Developing Countries								
Developing Asia	**304**	**479**	**496**	**586**	**683**	**793**	**888**	**2.8**
China	94	152	160	175	202	231	257	2.3
India	45	70	73	90	110	136	154	3.6
South Korea	38	60	62	68	74	77	79	1.2
Other Asia	127	197	201	254	298	349	397	3.3
Middle East	**155**	**195**	**198**	**215**	**226**	**245**	**267**	**1.4**
Turkey	17	22	22	27	29	32	36	2.4
Other Middle East	138	173	177	188	197	212	231	1.3
Africa	**83**	**95**	**97**	**121**	**139**	**153**	**169**	**2.7**
Central and South America	**132**	**173**	**176**	**199**	**222**	**236**	**255**	**1.8**
Brazil	51	70	71	77	85	95	107	2.0
Other Central/South America	81	104	105	122	137	142	148	1.6
Total Developing	**674**	**942**	**968**	**1,121**	**1,271**	**1,427**	**1,580**	**2.4**
Total World	**2,482**	**2,673**	**2,712**	**3,002**	**3,257**	**3,521**	**3,750**	**1.6**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.
Notes: EE/FSU = Eastern Europe/Former Soviet Union.
Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table B19; and World Energy Projection System (2002).

Table C12. World Carbon Dioxide Emissions from Natural Gas Use by Region, Low Economic Growth Case, 1990-2020
(Million Metric Tons Carbon Equivalent)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**326**	**377**	**381**	**443**	**481**	**524**	**557**	**1.8**
United States[a]	277	315	317	369	402	441	470	1.9
Canada	35	42	46	48	50	53	55	0.9
Mexico	15	20	19	25	29	31	31	2.4
Western Europe	**140**	**196**	**206**	**252**	**277**	**307**	**351**	**2.6**
United Kingdom	30	47	50	56	62	69	78	3.2
France	16	21	21	28	32	36	41	3.2
Germany	32	42	43	55	59	63	75	2.7
Italy	25	32	35	41	45	48	52	1.8
Netherlands	20	23	22	24	26	27	27	1.1
Other Western Europe	18	31	35	48	54	64	77	3.8
Industrialized Asia	**36**	**52**	**54**	**57**	**57**	**61**	**68**	**1.1**
Japan	24	38	40	40	39	42	48	0.9
Australasia	12	14	14	16	18	19	20	1.7
Total Industrialized	**503**	**626**	**641**	**751**	**815**	**892**	**976**	**2.0**
EE/FSU								
Former Soviet Union	369	291	294	298	316	345	375	1.2
Eastern Europe	46	36	35	43	55	69	81	4.0
Total EE/FSU	**414**	**327**	**329**	**340**	**371**	**415**	**455**	**1.6**
Developing Countries								
Developing Asia	**45**	**86**	**92**	**153**	**191**	**234**	**277**	**5.4**
China	8	13	14	27	38	55	71	7.9
India	7	13	12	18	24	31	36	5.1
South Korea	2	8	10	17	20	25	31	5.8
Other Asia	29	53	56	91	109	123	139	4.4
Middle East	**56**	**100**	**102**	**115**	**142**	**165**	**191**	**3.0**
Turkey	2	6	7	7	9	12	14	3.6
Other Middle East	54	94	96	108	133	154	176	3.0
Africa	**22**	**29**	**31**	**34**	**37**	**42**	**45**	**1.8**
Central and South America	**32**	**49**	**51**	**71**	**103**	**145**	**174**	**6.0**
Brazil	2	3	4	8	18	30	36	11.8
Other Central/South America	30	46	47	63	85	115	138	5.2
Total Developing	**155**	**263**	**276**	**374**	**474**	**587**	**687**	**4.4**
Total World	**1,072**	**1,216**	**1,247**	**1,466**	**1,660**	**1,894**	**2,118**	**2.6**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.
Notes: EE/FSU = Eastern Europe/Former Soviet Union.
Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table B19; and World Energy Projection System (2002).

Table C13. World Carbon Dioxide Emissions from Coal Use by Region, Low Economic Growth Case, 1990-2020
(Million Metric Tons Carbon Equivalent)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**520**	**595**	**592**	**657**	**689**	**703**	**722**	**1.0**
United States[a]	485	550	549	611	639	651	669	0.9
Canada	31	38	36	37	39	41	41	0.6
Mexico	4	7	6	9	10	11	12	3.3
Western Europe	**315**	**225**	**216**	**191**	**180**	**170**	**152**	**-1.7**
United Kingdom	68	42	39	36	33	30	24	-2.2
France	20	17	15	13	9	9	7	-3.5
Germany	137	87	83	74	73	70	65	-1.2
Italy	14	11	12	10	10	8	8	-1.8
Netherlands	11	13	11	10	7	6	5	-3.7
Other Western Europe	66	56	56	49	48	46	43	-1.2
Industrialized Asia	**104**	**130**	**135**	**137**	**137**	**137**	**135**	**0.0**
Japan	66	78	81	85	86	87	86	0.2
Australasia	38	52	53	52	51	50	49	-0.4
Total Industrialized	**939**	**951**	**943**	**985**	**1,006**	**1,009**	**1,009**	**0.3**
EE/FSU								
Former Soviet Union	333	160	168	160	145	130	114	-1.8
Eastern Europe	189	127	113	105	94	82	71	-2.2
Total EE/FSU	**522**	**287**	**280**	**265**	**239**	**213**	**185**	**-2.0**
Developing Countries								
Developing Asia	**704**	**870**	**773**	**905**	**1,001**	**1,073**	**1,156**	**1.9**
China	514	600	495	584	667	728	787	2.2
India	101	148	156	177	184	187	202	1.2
South Korea	21	33	36	40	42	44	45	1.1
Other Asia	67	88	87	104	108	114	122	1.6
Middle East	**20**	**30**	**29**	**29**	**33**	**33**	**33**	**0.7**
Turkey	16	23	21	22	23	24	24	0.4
Other Middle East	4	7	7	7	9	10	10	1.2
Africa	**74**	**93**	**90**	**91**	**90**	**90**	**90**	**0.0**
Central and South America	**15**	**23**	**22**	**24**	**24**	**23**	**24**	**0.4**
Brazil	9	14	13	15	16	16	17	1.3
Other Central/South America	5	9	9	9	8	7	6	-1.4
Total Developing	**812**	**1,017**	**914**	**1,049**	**1,147**	**1,220**	**1,303**	**1.7**
Total World	**2,274**	**2,254**	**2,137**	**2,300**	**2,392**	**2,442**	**2,496**	**0.7**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.
Notes: EE/FSU = Eastern Europe/Former Soviet Union.
Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table B19; and World Energy Projection System (2002).

Table C14. World Nuclear Generating Capacity by Region and Country, Low Economic Growth Case, 1999-2020
(Megawatts)

Region/Country	History		Projections			
	1999	2000	2005	2010	2015	2020
Industrialized Countries						
North America	**108,776**	**108,867**	**109,058**	**105,700**	**96,458**	**95,648**
United States	97,470	97,509	97,700	94,342	86,370	85,560
Canada	9,998	9,998	9,998	9,998	8,728	8,728
Mexico	1,308	1,360	1,360	1,360	1,360	1,360
Industrialized Asia	**43,691**	**43,491**	**44,043**	**46,223**	**42,935**	**38,710**
Japan	43,691	43,491	44,043	46,223	42,935	38,710
Western Europe	**125,991**	**125,726**	**120,781**	**112,222**	**100,536**	**82,708**
Belgium	5,712	5,712	5,712	5,712	4,358	3,966
Finland	2,656	2,656	2,656	2,656	2,656	1,328
France	63,103	63,153	62,920	62,920	61,080	53,030
Germany	21,122	21,122	18,975	16,179	13,134	11,859
Netherlands	449	449	0	0	0	0
Spain	7,470	7,512	7,512	6,913	6,913	6,913
Sweden	9,432	9,432	8,832	6,907	6,077	3,279
Switzerland	3,079	3,192	3,192	2,827	2,115	1,145
United Kingdom	12,968	12,498	10,982	8,108	4,203	1,188
Total Industrialized	**278,458**	**278,084**	**273,882**	**264,145**	**239,929**	**217,066**
EE/FSU						
Eastern Europe	**10,605**	**10,675**	**10,468**	**10,060**	**10,060**	**7,690**
Bulgaria	3,538	3,538	2,314	1,906	1,906	1,906
Czech Republic	1,648	1,648	3,481	3,481	3,481	3,481
Hungary	1,729	1,755	1,755	1,755	1,755	877
Romania	650	650	650	650	650	650
Slovakia	2,408	2,408	1,592	1,592	1,592	776
Slovenia	632	676	676	676	676	0
Former Soviet Union	**34,704**	**33,796**	**32,803**	**26,689**	**17,872**	**9,500**
Armenia	376	376	0	0	0	0
Lithuania	2,370	2,370	1,185	0	0	0
Russia	19,843	19,843	20,411	15,482	11,222	8,550
Ukraine	12,115	11,207	11,207	11,207	6,650	950
Total EE/FSU	**45,309**	**44,471**	**43,271**	**36,749**	**27,932**	**17,190**

See notes at end of table.

Table C14. World Nuclear Generating Capacity by Region and Country, Low Economic Growth Case, 1999-2020 (Continued)
(Megawatts)

Region/Country	History		Projections			
	1999	2000	2005	2010	2015	2020
Developing Countries						
Developing Asia	**22,063**	**22,777**	**28,784**	**33,368**	**38,107**	**40,399**
China	2,167	2,177	6,597	8,587	9,587	10,587
India	1,897	2,301	2,113	2,113	3,631	4,436
Korea, South	12,990	12,990	14,890	16,254	18,475	20,170
Pakistan	125	425	300	300	300	300
Taiwan	4,884	4,884	4,884	6,114	6,114	4,906
Central and South America	**1,561**	**2,790**	**2,455**	**2,455**	**1,829**	**1,229**
Argentina	935	935	600	600	600	0
Brazil	626	1,855	1,855	1,855	1,229	1,229
Middle East	**0**	**0**	**0**	**1,073**	**1,073**	**1,073**
Iran	0	0	0	1,073	1,073	1,073
Africa	**1,842**	**1,800**	**1,800**	**1,800**	**1,800**	**1,800**
South Africa	1,842	1,800	1,800	1,800	1,800	1,800
Total Developing	**25,466**	**27,367**	**33,039**	**38,696**	**42,809**	**44,501**
Total World	**349,233**	**349,922**	**350,192**	**339,590**	**310,670**	**278,757**

Sources: **History:** International Atomic Energy Agency, *Nuclear Power Reactors in the World 2000* (Vienna, Austria, April 2001). **Projections:** Energy Information Administration (EIA), *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table A9; and EIA, Office of Coal, Nuclear, Electric and Alternate Fuels, based on detailed assessments of country-specific nuclear power plants.

Table C15. World Total Energy Consumption in Oil-Equivalent Units by Region, Low Economic Growth Case, 1990-2020
(Million Tons Oil Equivalent)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**2,522**	**2,841**	**2,916**	**3,218**	**3,424**	**3,615**	**3,776**	**1.2**
United States[a]	2,121	2,383	2,446	2,687	2,849	3,003	3,128	1.2
Canada	275	305	316	340	354	362	366	0.7
Mexico	126	153	155	191	222	250	282	2.9
Western Europe	**1,508**	**1,659**	**1,664**	**1,751**	**1,792**	**1,829**	**1,872**	**0.6**
United Kingdom	234	251	250	264	272	280	287	0.7
France	222	256	258	275	283	288	295	0.6
Germany	373	357	352	373	379	385	392	0.5
Italy	176	201	203	214	220	225	229	0.6
Netherlands	85	96	97	101	103	106	108	0.5
Other Western Europe	419	498	504	524	535	545	562	0.5
Industrialized Asia	**574**	**695**	**704**	**714**	**726**	**742**	**755**	**0.3**
Japan	452	541	547	548	555	564	571	0.2
Australasia	122	153	157	166	172	178	184	0.8
Total Industrialized	**4,604**	**5,194**	**5,284**	**5,683**	**5,943**	**6,185**	**6,403**	**0.9**
EE/FSU								
Former Soviet Union	1,529	975	988	1,043	1,088	1,172	1,227	1.0
Eastern Europe	393	299	283	301	319	341	358	1.1
Total EE/FSU	**1,923**	**1,274**	**1,271**	**1,343**	**1,407**	**1,513**	**1,584**	**1.1**
Developing Countries								
Developing Asia	**1,286**	**1,837**	**1,788**	**2,207**	**2,540**	**2,873**	**3,193**	**2.8**
China	681	890	803	965	1,119	1,264	1,403	2.7
India	196	293	307	367	418	474	527	2.6
South Korea	92	173	185	217	235	259	280	2.0
Other Asia	317	481	492	658	768	876	983	3.4
Middle East	**330**	**481**	**487**	**537**	**607**	**680**	**761**	**2.1**
Turkey	50	76	74	83	93	102	113	2.0
Other Middle East	280	405	413	454	514	577	648	2.2
Africa	**235**	**292**	**297**	**338**	**365**	**398**	**425**	**1.7**
Central and South America	**346**	**489**	**498**	**578**	**662**	**751**	**829**	**2.5**
Brazil	142	208	215	237	266	295	322	2.0
Other Central/South America	204	282	283	342	395	456	507	2.8
Total Developing	**2,197**	**3,100**	**3,069**	**3,660**	**4,174**	**4,701**	**5,208**	**0.0**
Total World	**8,724**	**9,568**	**9,623**	**10,687**	**11,523**	**12,400**	**13,195**	**1.5**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.
Notes: EE/FSU = Eastern Europe/Former Soviet Union.
Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table B1; and World Energy Projection System (2002).

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, 1990-2020
(Million Barrels per Day)

Region/Country	History (Estimates)		Projections			
	1990	2000	2005	2010	2015	2020
OPEC						
Persian Gulf						
Iran	3.2	3.8	4.0	4.4	4.5	4.7
Iraq	2.2	2.6	3.1	3.9	4.5	5.5
Kuwait	1.7	2.5	2.8	3.5	4.1	4.8
Qatar	0.5	0.9	0.5	0.6	0.7	0.7
Saudi Arabia	8.6	9.4	12.5	14.6	18.2	22.1
United Arab Emitates	2.5	2.5	3.0	3.7	4.4	5.1
Total Persian Gulf	**18.7**	**21.7**	**25.9**	**30.7**	**36.4**	**42.9**
Other OPEC						
Algeria	1.3	1.4	1.9	2.2	2.3	2.5
Indonesia	1.5	1.6	1.5	1.5	1.5	1.5
Libya	1.5	1.5	2.1	2.5	2.8	3.2
Nigeria	1.8	2.1	2.8	3.3	4.0	4.7
Venezuela	2.4	3.1	4.2	4.6	5.0	5.4
Total Other OPEC	**8.5**	**9.7**	**12.5**	**14.1**	**15.6**	**17.3**
Total OPEC	**27.2**	**31.4**	**38.4**	**44.8**	**52.0**	**60.2**
Non-OPEC						
Industrialized						
United States	9.7	9.1	8.7	8.9	9.7	10.0
Canada	2.0	2.7	3.1	3.2	3.4	3.6
Mexico	3.0	3.5	3.9	4.2	4.4	4.4
Australia	0.7	0.9	0.8	0.8	0.8	0.8
North Sea	4.2	6.3	6.7	6.5	6.2	6.0
Other	0.5	0.8	0.8	0.8	0.8	0.8
Total Industrialized	**20.1**	**23.3**	**24.0**	**24.4**	**25.3**	**25.6**
Eurasia						
China	2.8	3.3	3.2	3.1	3.0	3.0
Former Soviet Union	11.4	8.1	10.1	12.1	13.8	14.9
Eastern Europe	0.3	0.2	0.2	0.3	0.3	0.4
Total Eurasia	**14.5**	**11.6**	**13.5**	**15.5**	**17.1**	**18.3**
Other Non-OPEC						
Central and South America	2.3	3.8	4.2	4.8	5.6	6.5
Middle East	1.4	2.0	2.2	2.4	2.5	2.4
Africa	2.2	2.9	3.1	3.9	4.7	5.8
Asia	1.7	2.4	2.6	2.6	2.6	2.5
Total Other Non-OPEC	**7.6**	**11.1**	**12.1**	**13.7**	**15.4**	**17.2**
Total Non-OPEC	**42.2**	**46.0**	**49.6**	**53.6**	**57.8**	**61.1**
Total World	**69.4**	**77.4**	**88.0**	**98.4**	**109.8**	**121.3**

Note: OPEC = Organization of Petroleum Exporting Countries.

Sources: **History:** Energy Information Administration (EIA), Energy Markets and Contingency Information Division. **Projections:** EIA, Office of Integrated Analysis and Forecasting, World Energy Projection System; and 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, 1990-2020
(Million Barrels per Day)

Region/Country	History (Estimates)		Projections			
	1990	2000	2005	2010	2015	2020
OPEC						
Persian Gulf						
Iran	3.2	3.8	3.8	4.1	4.2	4.5
Iraq	2.2	2.6	2.9	3.2	3.5	4.1
Kuwait	1.7	2.5	2.6	3.1	3.5	4.0
Qatar	0.5	0.9	0.5	0.6	0.7	0.7
Saudi Arabia	8.6	9.4	10.9	11.3	13.5	16.1
United Arab Emitates	2.5	2.5	2.6	2.8	3.1	3.5
Total Persian Gulf	**18.7**	**21.7**	**23.3**	**25.1**	**28.5**	**32.9**
Other OPEC						
Algeria	1.3	1.4	1.6	1.8	2.1	2.4
Indonesia	1.5	1.6	1.5	1.5	1.5	1.5
Libya	1.5	1.5	1.6	1.9	2.1	2.5
Nigeria	1.8	2.1	2.3	2.5	3.0	3.7
Venezuela	2.4	3.1	3.5	3.7	4.3	5.0
Total Other OPEC	**8.5**	**9.7**	**10.5**	**11.4**	**13.0**	**15.1**
Total OPEC	**27.2**	**31.4**	**33.8**	**36.5**	**41.5**	**48.0**
Non-OPEC						
Industrialized						
United States	9.7	9.1	9.0	9.3	10.4	11.1
Canada	2.0	2.7	3.2	3.5	3.7	3.9
Mexico	3.0	3.5	4.0	4.5	4.8	4.9
Australia	0.7	0.9	0.8	0.9	0.9	0.9
North Sea	4.2	6.3	6.8	6.7	6.5	6.2
Other	0.5	0.8	0.9	0.9	0.8	0.8
Total Industrialized	**20.1**	**23.3**	**24.7**	**25.8**	**27.1**	**27.8**
Eurasia						
China	2.8	3.3	3.3	3.3	3.2	3.3
Former Soviet Union	11.4	8.1	10.7	13.6	15.8	17.0
Eastern Europe	0.3	0.2	0.2	0.3	0.3	0.4
Total Eurasia	**14.5**	**11.6**	**14.2**	**17.2**	**19.3**	**20.7**
Other Non-OPEC						
Central and South America	2.3	3.8	4.4	5.4	6.4	7.4
Middle East	1.4	2.0	2.3	2.5	2.7	2.7
Africa	2.2	2.9	3.4	4.4	5.5	6.9
Asia	1.7	2.4	2.7	2.8	2.7	2.7
Total Other Non-OPEC	**7.6**	**11.1**	**12.8**	**15.1**	**17.3**	**19.7**
Total Non-OPEC	**42.2**	**46.0**	**51.7**	**58.1**	**63.7**	**68.2**
Total World	**69.4**	**77.4**	**85.5**	**94.6**	**105.2**	**116.2**

Note: OPEC = Organization of Petroleum Exporting Countries.

Sources: **History:** Energy Information Administration (EIA), Energy Markets and Contingency Information Division. **Projections:** EIA, Office of Integrated Analysis and Forecasting, World Energy Projection System; and 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, 1990-2020
(Million Barrels per Day)

Region/Country	History (Estimates)		Projections			
	1990	2000	2005	2010	2015	2020
OPEC						
Persian Gulf						
Iran	3.2	3.8	4.2	4.5	4.8	5.1
Iraq	2.2	2.6	3.4	4.2	5.1	6.0
Kuwait	1.7	2.5	3.0	3.7	4.5	5.3
Qatar	0.5	0.9	0.5	0.6	0.7	0.8
Saudi Arabia	8.6	9.4	14.9	18.3	23.1	28.3
United Arab Emitates	2.5	2.5	3.2	4.0	4.8	5.6
Total Persian Gulf	**18.7**	**21.7**	**29.2**	**35.3**	**43.0**	**51.1**
Other OPEC						
Algeria	1.3	1.4	1.8	2.3	2.5	2.8
Indonesia	1.5	1.6	1.5	1.5	1.5	1.5
Libya	1.5	1.5	2.2	2.7	3.2	3.6
Nigeria	1.8	2.1	2.7	3.6	4.2	4.7
Venezuela	2.4	3.1	3.9	4.7	5.1	5.9
Total Other OPEC	**8.5**	**9.7**	**12.1**	**14.8**	**16.5**	**18.5**
Total OPEC	**27.2**	**31.4**	**41.3**	**50.1**	**59.5**	**69.6**
Non-OPEC						
Industrialized						
United States	9.7	9.1	8.5	8.3	8.8	9.0
Canada	2.0	2.7	3.1	3.2	3.3	3.5
Mexico	3.0	3.5	3.8	4.1	4.2	4.3
Australia	0.7	0.9	0.8	0.8	0.8	0.8
North Sea	4.2	6.3	6.6	6.4	6.1	5.9
Other	0.5	0.8	0.8	0.8	0.8	0.7
Total Industrialized	**20.1**	**23.3**	**23.6**	**23.6**	**24.0**	**24.2**
Eurasia						
China	2.8	3.3	3.2	3.0	3.0	2.9
Former Soviet Union	11.4	8.1	9.9	11.9	13.4	14.5
Eastern Europe	0.3	0.2	0.2	0.3	0.3	0.3
Total Eurasia	**14.5**	**11.6**	**13.3**	**15.2**	**16.7**	**17.7**
Other Non-OPEC						
Central and South America	2.3	3.8	4.1	4.7	5.4	6.3
Middle East	1.4	2.0	2.2	2.3	2.5	2.4
Africa	2.2	2.9	3.1	3.8	4.6	5.6
Asia	1.7	2.4	2.6	2.6	2.5	2.5
Total Other Non-OPEC	**7.6**	**11.1**	**12.0**	**13.4**	**15.0**	**16.8**
Total Non-OPEC	**42.2**	**46.0**	**48.9**	**52.2**	**55.7**	**58.7**
Total World	**69.4**	**77.4**	**90.2**	**102.3**	**115.2**	**128.3**

Note: OPEC = Organization of Petroleum Exporting Countries.

Sources: **History:** Energy Information Administration (EIA), Energy Markets and Contingency Information Division. **Projections:** EIA, Office of Integrated Analysis and Forecasting, World Energy Projection System; and 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, 1990-2020
(Million Barrels per Day)

Region/Country	History (Estimates)		Projections			
	1990	2000	2005	2010	2015	2020
OPEC						
Persian Gulf	16.2	21.2	23.8	28.8	34.2	39.6
Other OPEC	8.3	9.7	11.5	13.3	15.2	17.6
Total OPEC	**24.5**	**30.9**	**35.3**	**42.1**	**49.4**	**57.2**
Non-OPEC						
Industrialized						
United States	9.7	9.1	8.7	8.9	9.7	10.0
Canada	2.0	2.7	3.1	3.2	3.4	3.6
Mexico	3.0	3.5	3.9	4.2	4.4	4.4
Western Europe	4.6	7.1	7.4	7.2	6.9	6.5
Other	0.8	0.9	0.9	0.9	0.9	0.9
Total Industrialized	**20.1**	**23.3**	**24.0**	**24.4**	**25.3**	**25.4**
Eurasia						
China	2.8	3.2	3.2	3.1	3.1	3.0
Former Soviet Union	11.4	8.2	10.1	12.1	13.7	14.9
Eastern Europe	0.3	0.2	0.2	0.3	0.3	0.4
Total Eurasia	**14.5**	**11.6**	**13.5**	**15.5**	**17.1**	**18.3**
Other Non-OPEC						
Central and South America	2.4	3.8	4.2	4.8	5.6	6.5
Pacific Rim	1.7	2.4	2.6	2.6	2.6	2.5
Other	3.5	4.8	5.3	6.3	7.2	8.4
Total Other Non-OPEC	**7.6**	**11.0**	**12.1**	**13.7**	**15.4**	**17.4**
Total Non-OPEC	**42.2**	**45.9**	**49.6**	**53.6**	**57.8**	**61.1**
Total World	**66.7**	**76.8**	**84.9**	**95.7**	**107.2**	**118.3**
Persian Gulf Production as a Percentage of World Consumption	**24.6**	**28.1**	**27.9**	**30.0**	**31.8**	**33.4**

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, Office of Integrated Analysis and Forecasting, World Energy Projection System; 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, 1990-2020
(Million Barrels per Day)

Region/Country	History (Estimates)		Projections			
	1990	2000	2005	2010	2015	2020
OPEC						
Persian Gulf	16.2	21.2	21.0	23.3	26.2	31.2
Other OPEC	8.3	9.7	10.1	11.0	13.2	14.4
Total OPEC	**24.5**	**30.9**	**31.1**	**34.3**	**39.4**	**45.6**
Non-OPEC						
Industrialized						
United States	9.7	9.1	9.0	9.3	10.4	11.1
Canada	2.0	2.7	3.2	3.5	3.7	3.9
Mexico	3.0	3.5	4.0	4.5	4.8	4.9
Western Europe	4.6	7.1	7.6	7.6	7.3	7.0
Other	0.8	0.9	0.9	0.9	0.9	0.9
Total Industrialized	**20.1**	**23.3**	**24.7**	**25.8**	**27.1**	**27.8**
Eurasia						
China	2.8	3.2	3.3	3.3	3.2	3.3
Former Soviet Union	11.4	8.2	10.7	13.6	15.8	17.0
Eastern Europe	0.3	0.2	0.2	0.3	0.3	0.4
Total Eurasia	**14.5**	**11.6**	**14.2**	**17.2**	**19.3**	**20.7**
Other Non-OPEC						
Central and South America	2.4	3.8	4.4	5.4	6.4	7.4
Pacific Rim	1.7	2.4	2.7	2.8	2.7	2.7
Other	3.5	4.8	5.7	6.9	8.2	9.6
Total Other Non-OPEC	**7.6**	**11.0**	**12.8**	**15.1**	**17.3**	**19.7**
Total Non-OPEC	**42.2**	**45.9**	**51.7**	**58.1**	**63.7**	**68.2**
Total World	**66.7**	**76.8**	**82.8**	**92.4**	**103.1**	**113.8**
Persian Gulf Production as a Percentage of World Consumption	**24.6**	**28.1**	**25.3**	**25.1**	**25.3**	**27.3**

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, Office of Integrated Analysis and Forecasting, World Energy Projection System; 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, 1990-2020
(Million Barrels per Day)

Region/Country	History (Estimates)		Projections			
	1990	2000	2005	2010	2015	2020
OPEC						
Persian Gulf	16.2	21.2	26.2	32.7	40.5	48.3
Other OPEC	8.3	9.7	11.8	14.4	16.0	17.9
Total OPEC	**24.5**	**30.9**	**38.0**	**47.1**	**56.5**	**66.2**
Non-OPEC						
Industrialized						
United States	9.7	9.1	8.5	8.3	8.8	9.0
Canada	2.0	2.7	3.1	3.2	3.3	3.5
Mexico	3.0	3.5	3.8	4.1	4.2	4.3
Western Europe	4.6	7.1	7.4	7.2	6.9	6.6
Other	0.8	0.9	0.8	0.8	0.8	0.8
Total Industrialized	**20.1**	**23.3**	**23.6**	**23.6**	**24.0**	**24.2**
Eurasia						
China	2.8	3.2	3.2	3.0	3.0	2.9
Former Soviet Union	11.4	8.2	9.9	11.9	13.4	14.5
Eastern Europe	0.3	0.2	0.2	0.3	0.3	0.3
Total Eurasia	**14.5**	**11.6**	**13.3**	**15.2**	**16.7**	**17.7**
Other Non-OPEC						
Central and South America	2.4	3.8	4.1	4.7	5.4	6.3
Pacific Rim	1.7	2.4	2.6	2.6	2.5	2.5
Other	3.5	4.8	5.3	6.0	7.1	8.0
Total Other Non-OPEC	**7.6**	**11.0**	**12.0**	**13.3**	**15.0**	**16.8**
Total Non-OPEC	**42.2**	**45.9**	**48.9**	**52.1**	**55.7**	**58.7**
Total World	**66.7**	**76.8**	**86.9**	**99.2**	**112.2**	**124.9**
Persian Gulf Production as a Percentage of World Consumption	**24.6**	**28.1**	**30.0**	**32.9**	**36.0**	**38.6**

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, Office of Integrated Analysis and Forecasting, World Energy Projection System; and U.S. Department of the Interior, U.S. Geological Survey, *World Petroleum Assessment 2000* (Reston, VA, July 2000).

Appendix E

Projections of Transportation Energy Use in the Reference Case

Table E1. World Total Energy Consumption for Transportation by Region, Reference Case, 1990-2020
(Million Barrels of Oil per Day)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**12.9**	**14.6**	**15.1**	**17.6**	**19.7**	**21.8**	**23.6**	**2.1**
United States[a]	11.4	12.9	13.3	15.3	17.0	18.6	19.9	1.9
Canada	0.9	1.0	1.0	1.1	1.2	1.3	1.4	1.4
Mexico	0.6	0.7	0.8	1.2	1.6	1.9	2.3	5.5
Western Europe	**6.3**	**7.6**	**7.4**	**8.1**	**8.5**	**8.9**	**9.3**	**1.1**
United Kingdom	1.0	1.1	1.1	1.2	1.3	1.4	1.5	1.5
France	1.0	1.0	1.0	1.1	1.2	1.3	1.3	1.2
Germany	1.3	1.6	1.5	1.6	1.7	1.8	1.8	0.9
Italy	0.8	1.0	0.9	1.0	1.0	1.0	1.1	0.7
Netherlands	0.4	0.5	0.5	0.6	0.6	0.6	0.6	1.0
Other Western Europe	1.8	2.4	2.4	2.6	2.7	2.8	2.9	1.0
Industrialized Asia	**2.1**	**2.7**	**2.8**	**3.0**	**3.2**	**3.3**	**3.4**	**1.1**
Japan	1.6	2.0	2.1	2.2	2.3	2.4	2.4	0.8
Australasia	0.6	0.7	0.7	0.8	0.9	0.9	1.0	1.8
Total Industrialized	**21.3**	**24.9**	**25.3**	**28.7**	**31.4**	**34.0**	**36.4**	**1.7**
EE/FSU								
Former Soviet Union	3.0	1.5	1.5	2.0	2.3	2.6	2.9	3.1
Eastern Europe	0.6	0.6	0.6	0.8	0.9	1.0	1.1	2.6
Total EE/FSU	**3.6**	**2.2**	**2.2**	**2.8**	**3.2**	**3.7**	**4.0**	**2.9**
Developing Countries								
Developing Asia	**3.3**	**5.5**	**5.7**	**7.7**	**10.0**	**13.0**	**15.6**	**4.9**
China	0.9	1.5	1.6	2.3	3.2	4.5	5.9	6.4
India	0.6	0.8	0.9	1.4	2.0	3.0	3.5	6.8
South Korea	0.3	0.6	0.7	0.9	1.0	1.1	1.1	2.7
Other Asia	1.5	2.5	2.6	3.2	3.8	4.4	5.0	3.2
Middle East	**1.4**	**1.7**	**1.7**	**1.8**	**1.8**	**1.9**	**1.9**	**0.6**
Turkey	0.2	0.2	0.2	0.3	0.3	0.4	0.4	2.2
Other Middle East	1.2	1.4	1.5	1.5	1.5	1.5	1.5	0.2
Africa	**1.0**	**1.2**	**1.2**	**1.5**	**1.7**	**1.9**	**2.2**	**2.9**
Central and South America	**1.9**	**2.5**	**2.6**	**2.8**	**3.4**	**4.0**	**4.9**	**3.1**
Brazil	0.8	1.0	1.1	1.2	1.3	1.5	1.7	2.3
Other Central/South America	1.1	1.5	1.5	1.7	2.1	2.6	3.2	3.7
Total Developing	**7.6**	**10.9**	**11.2**	**13.9**	**16.9**	**20.9**	**24.7**	**3.8**
Total World	**32.5**	**38.0**	**38.7**	**45.4**	**51.6**	**58.5**	**65.0**	**2.5**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

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

Sources: **History:** Derived from Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table A2; and World Energy Projection System (2002).

Table E2. World Total Gasoline Consumption for Transportation by Region, Reference Case, 1990-2020
(Million Barrels of Oil per Day)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**8.1**	**9.2**	**9.4**	**10.8**	**11.9**	**12.9**	**13.8**	**1.8**
United States[a]	7.1	8.1	8.3	9.3	10.2	11.0	11.6	1.6
Canada	0.6	0.6	0.6	0.7	0.7	0.8	0.8	1.0
Mexico	0.4	0.5	0.5	0.8	1.0	1.2	1.4	5.1
Western Europe	**2.9**	**2.9**	**2.9**	**3.0**	**3.1**	**3.1**	**3.1**	**0.3**
United Kingdom	0.6	0.5	0.5	0.5	0.5	0.6	0.6	0.5
France	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.2
Germany	0.7	0.8	0.7	0.8	0.8	0.8	0.8	0.2
Italy	0.3	0.5	0.4	0.4	0.5	0.5	0.5	0.2
Netherlands	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.6
Other Western Europe	0.7	0.8	0.8	0.8	0.9	0.9	0.9	0.3
Industrialized Asia	**1.1**	**1.3**	**1.3**	**1.4**	**1.5**	**1.5**	**1.5**	**0.7**
Japan	0.8	1.0	1.0	1.0	1.1	1.1	1.1	0.5
Australasia	0.3	0.4	0.4	0.4	0.4	0.4	0.5	1.1
Total Industrialized	**12.0**	**13.5**	**13.6**	**15.2**	**16.5**	**17.5**	**18.4**	**1.5**
EE/FSU								
Former Soviet Union	1.1	0.8	0.8	1.0	1.1	1.2	1.2	1.9
Eastern Europe	0.3	0.3	0.3	0.4	0.5	0.5	0.5	2.0
Total EE/FSU	**1.4**	**1.1**	**1.1**	**1.4**	**1.5**	**1.6**	**1.7**	**1.9**
Developing Countries								
Developing Asia	**1.0**	**1.8**	**1.9**	**2.6**	**3.4**	**4.5**	**5.4**	**5.1**
China	0.4	0.7	0.8	1.2	1.8	2.6	3.4	7.3
India	0.1	0.1	0.1	0.2	0.3	0.4	0.4	5.5
South Korea	0.1	0.2	0.2	0.2	0.2	0.3	0.3	2.1
Other Asia	0.5	0.8	0.8	1.0	1.1	1.3	1.3	2.3
Middle East	**0.6**	**0.9**	**0.9**	**0.9**	**0.9**	**0.9**	**0.9**	**0.0**
Turkey	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1.3
Other Middle East	0.5	0.8	0.8	0.8	0.8	0.8	0.8	-0.2
Africa	**0.5**	**0.5**	**0.5**	**0.7**	**0.8**	**0.9**	**1.0**	**2.8**
Central and South America	**0.9**	**1.0**	**1.0**	**1.1**	**1.4**	**1.8**	**2.3**	**3.9**
Brazil	0.3	0.3	0.3	0.4	0.4	0.5	0.6	3.2
Other Central/South America	0.6	0.7	0.7	0.8	1.0	1.3	1.7	4.1
Total Developing	**3.0**	**4.3**	**4.4**	**5.4**	**6.6**	**8.1**	**9.6**	**3.8**
Total World	**16.4**	**18.9**	**19.1**	**22.0**	**24.6**	**27.3**	**29.7**	**2.1**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

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

Sources: **History:** Derived from Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table A2; and World Energy Projection System (2002).

Table E3. World Total Diesel Fuel Consumption for Transportation by Region, Reference Case, 1990-2020
(Million Barrels of Oil per Day)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**2.1**	**2.7**	**2.8**	**3.5**	**4.1**	**4.5**	**4.9**	**2.6**
United States[a]	1.8	2.3	2.4	3.0	3.4	3.8	4.1	2.5
Canada	0.2	0.2	0.2	0.3	0.3	0.3	0.3	1.5
Mexico	0.2	0.2	0.2	0.3	0.4	0.4	0.5	4.8
Western Europe	**2.1**	**3.0**	**2.9**	**3.2**	**3.4**	**3.5**	**3.6**	**1.0**
United Kingdom	0.3	0.4	0.4	0.4	0.4	0.5	0.5	1.4
France	0.4	0.5	0.5	0.6	0.6	0.7	0.7	1.2
Germany	0.4	0.6	0.6	0.6	0.7	0.7	0.7	1.2
Italy	0.3	0.4	0.3	0.4	0.4	0.4	0.4	0.7
Netherlands	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.7
Other Western Europe	0.7	1.0	1.0	1.0	1.1	1.1	1.1	0.8
Industrialized Asia	**0.6**	**0.8**	**0.8**	**0.9**	**0.9**	**0.9**	**1.0**	**0.9**
Japan	0.5	0.6	0.6	0.7	0.7	0.7	0.7	0.6
Australasia	0.1	0.2	0.2	0.2	0.2	0.2	0.2	1.7
Total Industrialized	**4.9**	**6.5**	**6.6**	**7.6**	**8.3**	**9.0**	**9.5**	**1.8**
EE/FSU								
Former Soviet Union	0.9	0.3	0.3	0.5	0.6	0.7	0.7	3.7
Eastern Europe	0.2	0.2	0.2	0.3	0.3	0.4	0.4	2.7
Total EE/FSU	**1.1**	**0.6**	**0.6**	**0.8**	**0.9**	**1.0**	**1.1**	**3.3**
Developing Countries								
Developing Asia	**1.2**	**2.3**	**2.4**	**3.3**	**4.3**	**5.7**	**6.8**	**5.1**
China	0.1	0.4	0.4	0.6	0.9	1.3	1.8	6.9
India	0.4	0.6	0.7	1.1	1.6	2.4	2.8	7.0
South Korea	0.2	0.2	0.2	0.3	0.4	0.4	0.4	3.2
Other Asia	0.5	1.0	1.0	1.3	1.5	1.7	1.8	2.7
Middle East	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.4**
Turkey	0.1	0.1	0.1	0.1	0.1	0.1	0.1	2.5
Other Middle East	0.4	0.4	0.4	0.4	0.4	0.4	0.4	-0.2
Africa	**0.3**	**0.3**	**0.3**	**0.4**	**0.5**	**0.6**	**0.6**	**2.8**
Central and South America	**0.6**	**0.9**	**1.0**	**1.0**	**1.2**	**1.3**	**1.5**	**2.2**
Brazil	0.3	0.4	0.5	0.5	0.5	0.5	0.5	0.6
Other Central/South America	0.3	0.5	0.5	0.6	0.7	0.8	1.0	3.4
Total Developing	**2.6**	**4.1**	**4.2**	**5.3**	**6.5**	**8.1**	**9.4**	**4.0**
Total World	**8.6**	**11.1**	**11.3**	**13.7**	**15.8**	**18.1**	**20.0**	**2.8**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

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

Sources: **History:** Derived from Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table A2; and World Energy Projection System (2002).

Table E4. World Total Jet Fuel Consumption for Transportation by Region, Reference Case, 1990-2020
(Million Barrels of Oil per Day)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**1.6**	**1.8**	**1.8**	**2.1**	**2.4**	**2.8**	**3.3**	**2.9**
United States[a]	1.5	1.6	1.7	1.9	2.2	2.5	2.8	2.5
Canada	0.1	0.1	0.1	0.1	0.1	0.1	0.2	1.5
Mexico	0.0	0.1	0.1	0.1	0.1	0.2	0.4	9.7
Western Europe	**0.6**	**0.9**	**0.8**	**1.1**	**1.3**	**1.5**	**1.7**	**3.4**
United Kingdom	0.1	0.2	0.2	0.2	0.3	0.3	0.4	3.5
France	0.1	0.1	0.1	0.1	0.2	0.2	0.2	3.1
Germany	0.1	0.1	0.1	0.2	0.2	0.2	0.2	3.0
Italy	0.0	0.1	0.1	0.1	0.1	0.1	0.1	3.5
Netherlands	0.0	0.1	0.1	0.1	0.1	0.1	0.1	3.2
Other Western Europe	0.2	0.3	0.3	0.4	0.4	0.5	0.6	3.7
Industrialized Asia	**0.1**	**0.3**	**0.3**	**0.4**	**0.4**	**0.5**	**0.6**	**3.1**
Japan	0.1	0.2	0.2	0.2	0.3	0.3	0.3	2.4
Australasia	0.1	0.1	0.1	0.1	0.2	0.2	0.2	4.3
Total Industrialized	**2.4**	**3.0**	**3.0**	**3.5**	**4.1**	**4.8**	**5.7**	**3.1**
EE/FSU								
Former Soviet Union	0.5	0.3	0.3	0.3	0.4	0.6	0.7	4.8
Eastern Europe	0.0	0.0	0.0	0.0	0.1	0.1	0.1	7.6
Total EE/FSU	**0.6**	**0.3**	**0.3**	**0.4**	**0.5**	**0.7**	**0.8**	**5.2**
Developing Countries								
Developing Asia	**0.4**	**0.5**	**0.5**	**0.8**	**1.1**	**1.6**	**2.1**	**6.9**
China	0.1	0.1	0.1	0.1	0.2	0.3	0.3	6.2
India	0.0	0.0	0.0	0.1	0.1	0.2	0.3	9.1
South Korea	0.0	0.0	0.0	0.1	0.1	0.1	0.2	5.9
Other Asia	0.2	0.3	0.3	0.5	0.7	1.0	1.3	6.9
Middle East	**0.2**	**0.2**	**0.2**	**0.2**	**0.3**	**0.3**	**0.3**	**2.3**
Turkey	0.0	0.0	0.0	0.0	0.1	0.1	0.1	4.8
Other Middle East	0.2	0.2	0.2	0.2	0.2	0.2	0.2	1.6
Africa	**0.1**	**0.1**	**0.1**	**0.2**	**0.2**	**0.3**	**0.3**	**5.1**
Central and South America	**0.1**	**0.2**	**0.2**	**0.2**	**0.3**	**0.4**	**0.5**	**4.7**
Brazil	0.0	0.0	0.0	0.1	0.1	0.1	0.1	5.4
Other Central/South America	0.1	0.1	0.1	0.2	0.2	0.3	0.3	4.4
Total Developing	**0.8**	**1.0**	**1.0**	**1.4**	**1.9**	**2.5**	**3.3**	**5.7**
Total World	**3.8**	**4.2**	**4.3**	**5.3**	**6.5**	**8.0**	**9.8**	**4.0**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

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

Sources: **History:** Derived from Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table A2; and World Energy Projection System (2002).

Table E5. World Total Residual Fuel Consumption for Transportation by Region, Reference Case, 1990-2020
(Million Barrels of Oil per Day)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**0.5**	**0.3**	**0.4**	**0.5**	**0.5**	**0.5**	**0.5**	**0.8**
United States[a]	0.4	0.3	0.4	0.5	0.5	0.5	0.5	0.8
Canada	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
Mexico	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
Western Europe	**0.5**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.3**
United Kingdom	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
France	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Germany	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Italy	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Netherlands	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3
Other Western Europe	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Industrialized Asia	**0.1**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.6**
Japan	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.5
Australasia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
Total Industrialized	**1.1**	**1.1**	**1.2**	**1.3**	**1.3**	**1.4**	**1.4**	**0.5**
EE/FSU								
Former Soviet Union	0.2	0.0	0.0	0.0	0.0	0.0	0.1	5.2
Eastern Europe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6
Total EE/FSU	**0.2**	**0.0**	**0.0**	**0.1**	**0.1**	**0.1**	**0.1**	**3.3**
Developing Countries								
Developing Asia	**0.3**	**0.7**	**0.7**	**0.7**	**0.8**	**0.9**	**0.9**	**1.5**
China	0.0	0.1	0.1	0.1	0.1	0.1	0.2	1.4
India	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7
South Korea	0.0	0.1	0.1	0.2	0.2	0.2	0.2	1.4
Other Asia	0.2	0.4	0.4	0.4	0.5	0.5	0.6	1.5
Middle East	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**1.9**
Turkey	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2
Other Middle East	0.1	0.1	0.1	0.1	0.1	0.1	0.1	2.0
Africa	**0.1**	**0.1**	**0.1**	**0.2**	**0.2**	**0.2**	**0.2**	**1.2**
Central and South America	**0.1**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.7**
Brazil	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.9
Other Central/South America	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.6
Total Developing	**0.7**	**1.0**	**1.1**	**1.2**	**1.3**	**1.3**	**1.4**	**1.4**
Total World	**2.0**	**2.2**	**2.4**	**2.5**	**2.7**	**2.8**	**2.9**	**1.0**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

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

Sources: **History:** Derived from Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table A2; and World Energy Projection System (2002).

Table E6. World Total Other Fuel Consumption for Transportation by Region, Reference Case, 1990-2020
(Million Barrels of Oil per Day)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**0.6**	**0.6**	**0.6**	**0.7**	**0.8**	**0.9**	**1.1**	**2.6**
United States[a]	0.5	0.5	0.6	0.7	0.7	0.8	1.0	2.4
Canada	0.0	0.0	0.0	0.0	0.0	0.1	0.1	6.4
Mexico	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6
Western Europe	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.6**
United Kingdom	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
France	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Germany	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Italy	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3
Netherlands	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2
Other Western Europe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2
Industrialized Asia	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.2**	**0.2**	**0.9**
Japan	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.7
Australasia	0.0	0.0	0.0	0.1	0.1	0.1	0.1	1.3
Total Industrialized	**0.8**	**0.9**	**1.0**	**1.1**	**1.2**	**1.3**	**1.5**	**2.0**
EE/FSU								
Former Soviet Union	0.3	0.1	0.1	0.1	0.2	0.2	0.2	3.8
Eastern Europe	0.0	0.0	0.0	0.0	0.1	0.1	0.1	1.0
Total EE/FSU	**0.3**	**0.1**	**0.1**	**0.2**	**0.2**	**0.3**	**0.3**	**3.1**
Developing Countries								
Developing Asia	**0.3**	**0.2**	**0.3**	**0.3**	**0.3**	**0.3**	**0.4**	**1.5**
China	0.2	0.2	0.2	0.2	0.2	0.2	0.2	1.1
India	0.1	0.0	0.0	0.0	0.0	0.0	0.0	1.5
South Korea	0.0	0.1	0.1	0.1	0.1	0.1	0.1	1.8
Other Asia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.3
Middle East	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.2**
Turkey	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Other Middle East	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Africa	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.1**	**2.0**
Central and South America	**0.1**	**0.2**	**0.2**	**0.3**	**0.3**	**0.4**	**0.5**	**3.1**
Brazil	0.1	0.2	0.2	0.2	0.3	0.3	0.4	3.3
Other Central/South America	0.0	0.1	0.1	0.1	0.1	0.1	0.1	2.4
Total Developing	**0.5**	**0.5**	**0.6**	**0.6**	**0.7**	**0.8**	**0.9**	**2.3**
Total World	**1.6**	**1.6**	**1.7**	**1.9**	**2.1**	**2.4**	**2.7**	**2.2**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

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

Sources: **History:** Derived from Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001), Table A2; and World Energy Projection System (2002).

Table E7. World Total Road Use Energy Consumption by Region, Reference Case, 1990-2020
(Million Barrels of Oil per Day)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**9.9**	**11.7**	**12.1**	**14.3**	**16.0**	**17.6**	**18.9**	**2.1**
United States[a]	8.7	10.3	10.6	12.3	13.7	14.9	15.9	1.9
Canada	0.7	0.8	0.8	0.9	1.0	1.0	1.1	1.4
Mexico	0.6	0.7	0.7	1.1	1.4	1.6	1.9	5.0
Western Europe	**4.7**	**5.5**	**5.4**	**5.8**	**6.0**	**6.1**	**6.2**	**0.7**
United Kingdom	0.8	0.8	0.8	0.9	0.9	0.9	1.0	1.0
France	0.8	0.8	0.8	0.9	0.9	1.0	1.0	0.9
Germany	1.1	1.3	1.3	1.3	1.4	1.4	1.4	0.7
Italy	0.6	0.8	0.8	0.8	0.8	0.9	0.9	0.4
Netherlands	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.8
Other Western Europe	1.2	1.6	1.6	1.7	1.7	1.7	1.8	0.6
Industrialized Asia	**1.6**	**2.1**	**2.1**	**2.2**	**2.3**	**2.4**	**2.5**	**0.7**
Japan	1.2	1.6	1.6	1.7	1.7	1.8	1.8	0.5
Australasia	0.4	0.5	0.5	0.6	0.6	0.6	0.7	1.3
Total Industrialized	**16.2**	**19.3**	**19.6**	**22.3**	**24.4**	**26.1**	**27.6**	**1.6**
EE/FSU								
Former Soviet Union	1.6	1.1	1.0	1.4	1.7	1.9	2.1	3.3
Eastern Europe	0.5	0.5	0.5	0.7	0.8	0.8	0.9	2.3
Total EE/FSU	**2.1**	**1.6**	**1.6**	**2.1**	**2.5**	**2.8**	**2.9**	**3.0**
Developing Countries								
Developing Asia	**2.0**	**3.7**	**3.8**	**5.4**	**7.1**	**9.4**	**11.2**	**5.2**
China	0.5	0.9	1.0	1.5	2.2	3.3	4.5	7.6
India	0.4	0.7	0.8	1.3	1.9	2.8	3.2	7.0
South Korea	0.2	0.4	0.4	0.5	0.6	0.6	0.7	2.7
Other Asia	0.9	1.7	1.7	2.1	2.4	2.7	2.8	2.4
Middle East	**1.1**	**1.4**	**1.4**	**1.5**	**1.5**	**1.5**	**1.5**	**0.2**
Turkey	0.2	0.2	0.2	0.2	0.3	0.3	0.3	1.8
Other Middle East	0.9	1.2	1.2	1.2	1.2	1.2	1.2	-0.1
Africa	**0.8**	**0.8**	**0.9**	**1.1**	**1.3**	**1.4**	**1.6**	**2.9**
Central and South America	**1.6**	**2.1**	**2.1**	**2.3**	**2.8**	**3.3**	**4.1**	**3.2**
Brazil	0.7	0.9	0.9	1.0	1.1	1.2	1.4	2.2
Other Central/South America	0.9	1.2	1.2	1.4	1.7	2.1	2.7	3.8
Total Developing	**5.4**	**8.0**	**8.2**	**10.3**	**12.6**	**15.6**	**18.3**	**3.9**
Total World	**23.7**	**28.9**	**29.4**	**34.8**	**39.5**	**44.5**	**48.9**	**2.4**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

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

Sources: **History:** Derived from Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

Table E8. World Total Air Use Energy Consumption by Region, Reference Case, 1990-2020
(Million Barrels of Oil per Day)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**1.6**	**1.8**	**1.8**	**2.1**	**2.4**	**2.8**	**3.3**	**2.9**
United States[a]	1.5	1.6	1.7	1.9	2.2	2.5	2.8	2.5
Canada	0.1	0.1	0.1	0.1	0.1	0.1	0.2	1.5
Mexico	0.0	0.1	0.1	0.1	0.1	0.2	0.4	9.7
Western Europe	**0.6**	**0.9**	**0.8**	**1.1**	**1.3**	**1.5**	**1.7**	**3.4**
United Kingdom	0.1	0.2	0.2	0.2	0.3	0.3	0.4	3.5
France	0.1	0.1	0.1	0.1	0.2	0.2	0.2	3.1
Germany	0.1	0.1	0.1	0.2	0.2	0.2	0.2	3.0
Italy	0.0	0.1	0.1	0.1	0.1	0.1	0.1	3.5
Netherlands	0.0	0.1	0.1	0.1	0.1	0.1	0.1	3.2
Other Western Europe	0.2	0.3	0.3	0.4	0.4	0.5	0.6	3.7
Industrialized Asia	**0.1**	**0.3**	**0.3**	**0.4**	**0.4**	**0.5**	**0.6**	**3.1**
Japan	0.1	0.2	0.2	0.2	0.3	0.3	0.3	2.4
Australasia	0.1	0.1	0.1	0.1	0.2	0.2	0.2	4.3
Total Industrialized	**2.4**	**3.0**	**3.0**	**3.5**	**4.1**	**4.8**	**5.7**	**3.1**
EE/FSU								
Former Soviet Union	0.5	0.3	0.3	0.3	0.4	0.6	0.7	4.8
Eastern Europe	0.0	0.0	0.0	0.0	0.1	0.1	0.1	7.6
Total EE/FSU	**0.6**	**0.3**	**0.3**	**0.4**	**0.5**	**0.7**	**0.8**	**5.2**
Developing Countries								
Developing Asia	**0.4**	**0.5**	**0.5**	**0.8**	**1.1**	**1.6**	**2.1**	**6.9**
China	0.1	0.1	0.1	0.1	0.2	0.3	0.3	6.2
India	0.0	0.0	0.0	0.1	0.1	0.2	0.3	9.1
South Korea	0.0	0.0	0.0	0.1	0.1	0.1	0.2	5.9
Other Asia	0.2	0.3	0.3	0.5	0.7	1.0	1.3	6.9
Middle East	**0.2**	**0.2**	**0.2**	**0.2**	**0.3**	**0.3**	**0.3**	**2.3**
Turkey	0.0	0.0	0.0	0.0	0.1	0.1	0.1	4.8
Other Middle East	0.2	0.2	0.2	0.2	0.2	0.2	0.2	1.6
Africa	**0.1**	**0.1**	**0.1**	**0.2**	**0.2**	**0.3**	**0.3**	**5.1**
Central and South America	**0.1**	**0.2**	**0.2**	**0.2**	**0.3**	**0.4**	**0.5**	**4.7**
Brazil	0.0	0.0	0.0	0.1	0.1	0.1	0.1	5.4
Other Central/South America	0.1	0.1	0.1	0.2	0.2	0.3	0.3	4.4
Total Developing	**0.8**	**1.0**	**1.0**	**1.4**	**1.9**	**2.5**	**3.3**	**5.7**
Total World	**3.8**	**4.2**	**4.3**	**5.3**	**6.5**	**8.0**	**9.8**	**4.0**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

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

Sources: **History:** Derived from Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

Table E9. World Total Other Transportation Use Energy Consumption by Region, Reference Case, 1990-2020
(Million Barrels of Oil per Day)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**1.3**	**1.1**	**1.2**	**1.3**	**1.3**	**1.3**	**1.4**	**0.8**
United States[a]	1.2	1.0	1.0	1.1	1.1	1.2	1.2	0.7
Canada	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1.0
Mexico	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.2
Western Europe	**1.1**	**1.2**	**1.2**	**1.3**	**1.3**	**1.3**	**1.3**	**0.4**
United Kingdom	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.5
France	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.5
Germany	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3
Italy	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.4
Netherlands	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.4
Other Western Europe	0.4	0.5	0.5	0.5	0.6	0.6	0.6	0.5
Industrialized Asia	**0.4**	**0.3**	**0.3**	**0.4**	**0.4**	**0.4**	**0.4**	**0.7**
Japan	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.6
Australasia	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1.2
Total Industrialized	**2.7**	**2.7**	**2.7**	**2.9**	**2.9**	**3.0**	**3.1**	**0.6**
EE/FSU								
Former Soviet Union	0.9	0.2	0.2	0.2	0.2	0.1	0.1	-2.5
Eastern Europe	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1.5
Total EE/FSU	**1.0**	**0.3**	**0.3**	**0.3**	**0.3**	**0.2**	**0.2**	**-1.0**
Developing Countries								
Developing Asia	**0.9**	**1.3**	**1.4**	**1.6**	**1.8**	**2.0**	**2.3**	**2.5**
China	0.3	0.5	0.5	0.6	0.8	0.9	1.1	3.4
India	0.1	0.1	0.1	0.1	0.0	0.0	0.0	-3.1
South Korea	0.1	0.2	0.2	0.3	0.3	0.3	0.3	1.7
Other Asia	0.3	0.6	0.6	0.6	0.7	0.8	0.9	2.1
Middle East	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.7**
Turkey	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.3
Other Middle East	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.8
Africa	**0.1**	**0.2**	**0.2**	**0.2**	**0.2**	**0.3**	**0.3**	**1.2**
Central and South America	**0.2**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.4**	**1.4**
Brazil	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1.3
Other Central/South America	0.1	0.2	0.2	0.2	0.2	0.2	0.2	1.5
Total Developing	**1.3**	**1.9**	**2.0**	**2.2**	**2.4**	**2.7**	**3.0**	**2.1**
Total World	**5.0**	**4.9**	**5.0**	**5.3**	**5.6**	**6.0**	**6.4**	**1.2**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.
Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding.
Sources: **History:** Derived from Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

Table E10. World Per Capita Vehicle Ownership (Motorization) by Region, Reference Case, 1990-2020
(Vehicles per Thousand Population)

Region/Country	History (Estimates)			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**601**	**612**	**614**	**630**	**645**	**664**	**689**	**0.5**
United States[a]	765	775	777	787	792	795	797	0.1
Canada	596	598	607	646	665	678	686	0.6
Mexico	119	154	158	201	251	318	410	4.6
Western Europe	**473**	**522**	**528**	**553**	**568**	**582**	**597**	**0.6**
United Kingdom	457	509	517	552	569	580	587	0.6
France	502	552	560	598	617	629	636	0.6
Germany	485	551	559	592	609	619	626	0.5
Italy	525	603	612	649	667	679	687	0.6
Netherlands	385	428	435	462	476	485	490	0.6
Other Western Europe	384	445	450	471	481	488	492	0.4
Industrialized Asia	**638**	**608**	**615**	**648**	**667**	**684**	**702**	**0.6**
Japan	467	562	569	603	620	631	638	0.5
Australasia	617	637	642	666	678	686	691	0.4
Total Industrialized	**638**	**608**	**615**	**648**	**667**	**684**	**702**	**0.6**
EE/FSU								
Former Soviet Union	357	128	134	162	176	184	190	1.7
Eastern Europe	213	209	217	251	269	280	287	1.4
Total EE/FSU	**314**	**152**	**158**	**188**	**203**	**212**	**218**	**1.5**
Developing Countries								
Developing Asia	**10**	**19**	**20**	**28**	**35**	**44**	**53**	**4.6**
China	5	11	12	18	27	40	52	7.5
India	5	9	10	15	22	33	44	7.6
South Korea	79	250	268	344	382	407	422	2.2
Other Asia	18	30	32	40	43	46	47	1.9
Middle East	**38**	**56**	**57**	**68**	**80**	**98**	**124**	**3.8**
Turkey	42	80	83	100	108	114	117	1.6
Other Middle East	37	50	50	60	73	94	126	4.5
Africa	**24**	**25**	**26**	**30**	**32**	**33**	**34**	**1.3**
Central and South America	**78**	**99**	**100**	**126**	**155**	**191**	**236**	**4.2**
Brazil	81	101	101	131	163	201	248	4.4
Other Central/South America	58	75	75	93	112	134	160	3.7
Total Developing	**21**	**31**	**32**	**41**	**50**	**61**	**73**	**4.0**
Total World	**124**	**121**	**122**	**130**	**136**	**143**	**150**	**1.0**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.
Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding.
Sources: **History:** Derived from American Automobile Manufacturers Association, *World Motor Vehicle Data* (Detroit, MI, 1997). **Projections:** Energy Information Administration, World Energy Projection System (2002).

Table E11. World Per Capita Transportation Energy Use by Region, Reference Case, 1990-2020
(Barrels Oil Equivalent per Person)

Region/Country	History (Estimates)			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**12.8**	**13.5**	**13.8**	**15.1**	**16.1**	**17.1**	**17.8**	**1.2**
United States[a]	16.3	17.4	17.8	19.4	20.6	21.7	22.4	1.1
Canada	11.7	12.0	12.4	13.0	13.5	13.8	14.1	0.6
Mexico	2.7	2.8	2.9	4.2	5.1	5.9	6.8	4.2
Western Europe	**6.1**	**6.8**	**7.0**	**7.6**	**8.0**	**8.4**	**8.7**	**1.1**
United Kingdom	6.5	6.7	6.7	7.4	7.9	8.4	8.9	1.3
France	6.3	6.4	6.4	6.9	7.2	7.5	7.7	0.9
Germany	6.0	6.1	6.7	7.3	7.6	8.0	8.3	1.0
Italy	4.9	5.4	5.9	6.3	6.6	6.9	7.3	1.0
Netherlands	10.4	11.7	12.2	12.8	13.3	13.8	14.3	0.8
Other Western Europe	6.0	7.5	7.5	8.1	8.5	9.0	9.4	1.1
Industrialized Asia	**5.2**	**6.1**	**6.5**	**6.9**	**7.3**	**7.6**	**8.0**	**0.9**
Japan	4.6	5.6	5.9	6.2	6.5	6.7	7.0	0.8
Australasia	8.6	8.8	9.6	10.2	10.7	11.2	11.8	1.0
Total Industrialized	**8.7**	**9.5**	**9.8**	**10.8**	**11.5**	**12.2**	**12.9**	**1.3**
EE/FSU								
Former Soviet Union	3.8	1.7	1.9	2.5	2.9	3.4	3.8	3.3
Eastern Europe	1.7	1.9	2.0	2.5	2.9	3.2	3.5	2.8
Total EE/FSU	**3.2**	**1.8**	**1.9**	**2.5**	**2.9**	**3.4**	**3.7**	**3.2**
Developing Countries								
Developing Asia	**0.4**	**0.6**	**0.7**	**0.8**	**1.0**	**1.2**	**1.4**	**3.7**
China	0.3	0.4	0.5	0.6	0.8	1.2	1.5	5.7
India	0.2	0.3	0.3	0.5	0.6	0.9	1.0	5.5
South Korea	3.0	5.6	5.1	6.5	7.2	7.7	8.2	2.2
Other Asia	0.7	1.0	1.1	1.2	1.3	1.4	1.5	1.7
Middle East	**2.6**	**2.6**	**2.7**	**2.5**	**2.3**	**2.1**	**2.0**	**-1.4**
Turkey	1.3	1.6	1.4	1.5	1.6	1.7	1.7	1.1
Other Middle East	3.2	3.0	3.2	2.8	2.5	2.3	2.1	-2.0
Africa	**0.6**	**0.5**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**
Central and South America	**2.0**	**1.9**	**2.3**	**2.3**	**2.6**	**2.9**	**3.4**	**1.9**
Brazil	2.0	1.9	2.3	2.3	2.5	2.7	3.0	1.2
Other Central/South America	2.0	1.9	2.3	2.3	2.6	3.1	3.7	2.2
Total Developing	**0.7**	**0.8**	**0.9**	**1.0**	**1.1**	**1.3**	**1.5**	**2.4**
Total World	**2.3**	**2.3**	**2.4**	**2.6**	**2.8**	**3.0**	**3.1**	**1.3**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

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

Sources: **History:** Derived from Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001), and United Nations, *World Population Prospects: The 2000 Revision* (New York, NY, 2001). **Projections:** EIA, World Energy Projection System (2002).

Appendix F

World Energy Projection System

The projections of world energy consumption published annually by the Energy Information Administration (EIA) in the *International Energy Outlook (IEO)* are derived from the World Energy Projection System (WEPS). WEPS is an integrated set of personal-computer-based spreadsheets containing data compilations, assumption specifications, descriptive analysis procedures, and projection models. The WEPS accounting framework incorporates projections from independently documented models and assumptions about the future energy intensity of economic activity (ratios of total energy consumption divided by gross domestic product [GDP]) and about the rate of incremental energy requirements met by natural gas, coal, and renewable energy sources (hydroelectricity, geothermal, solar, wind, biomass, and other renewable sources).

WEPS provides projections of total world primary energy consumption, as well as projections of energy consumption by primary energy type (oil, natural gas, coal, nuclear, and hydroelectric and other renewable resources), and projections of net electricity consumption and energy use in the transportation sector. Projections of energy consumed by fuel type are also provided for electricity generation and for transportation. Carbon dioxide emissions resulting from fossil fuel use are derived from the energy consumption projections. All projections are computed in 5-year intervals through the year 2020. For both historical series and projection series, WEPS provides analytical computations of energy intensity and energy elasticity (the percentage change in energy consumption per percentage change in GDP).

WEPS projections are provided for regions and selected countries. Projections are made for 14 individual countries, 9 of which—United States, Canada, Mexico, Japan, United Kingdom, France, Germany, Italy, and Netherlands—are part of the designation "industrialized countries." Individual country projections are also made for China, India, South Korea, Turkey, and Brazil, all of which are considered "developing countries." Beyond these individual countries, the rest of the world is divided into regions. Industrialized regions include North America (Canada, Mexico, and the United States), Western Europe (United Kingdom, France, Germany, Italy, Netherlands, and Other Europe), and Pacific (Japan and Australasia, which consists of Australia, New Zealand, and the U.S. Territories). Developing regions include developing Asia (China, India, South Korea, and Other Asia), Middle East (Turkey and Other Middle East), Africa, and Central and South America (Brazil and Other Central and South America). The transitional economies, consisting of the countries in Eastern Europe (EE) and the former Soviet Union (FSU), are considered as a separate country grouping, neither industrialized nor developing. Within the EE/FSU, projections are made separately for nations designated as Annex I and non-Annex I in the Kyoto Climate Change Protocol.

The process of creating the projections begins with the calculation of a reference case total energy consumption projection for each country or region for each 5-year interval in the forecast period. The total energy consumption projection for each forecast year is the product of an assumed GDP growth rate, an assumed energy elasticity, and the total energy consumption for the prior forecast year. For the first year of the forecast, the prior year consumption is based on historical data. Subsequent calculations are based on the energy consumption projections for the preceding years.

Projections of world oil supply are provided to WEPS from EIA's International Energy Module, which is a submodule of the National Energy Modeling System (NEMS). Projections of world nuclear energy consumption are derived from nuclear power electricity generation projections from EIA's International Nuclear Model (INM), PC Version (PC-INM). All U.S. projections are taken from EIA's *Annual Energy Outlook (AEO)*.

A full description of WEPS is provided in a model documentation report: Energy Information Administration, *World Energy Projection System Model Documentation*, DOE/EIA-M050(97) (Washington, DC, September 1997). The report presents a description of each of the spreadsheets associated with WEPS, along with descriptions of the methodologies and assumptions used to produce the projections. The entire publication can be found through the Internet in portable document format (PDF) at: ftp://ftp.eia.doe.gov/pub/pdf/model.docs/m05097.pdf.

The WEPS model will be made available for downloading through the Internet on EIA's home page by May 2002. The package will allow users to replicate the projections that appear in *IEO2002*. It is coded in Excel, version 5.0, and can be executed on any IBM-compatible personal computer in a Windows environment. The package requires about 14 megabytes of hard disk space for complete installation and model execution.

Appendix G

Performance of Past *IEO* Forecasts for 1990 and 1995

In an effort to measure how well the *IEO* projections have estimated future energy consumption trends over the series' 17-year history, we present a comparison of *IEO* forecasts produced for the years 1990 and 1995. The forecasts are compared with actual data published in EIA's *International Energy Annual 1999*,[39] 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.

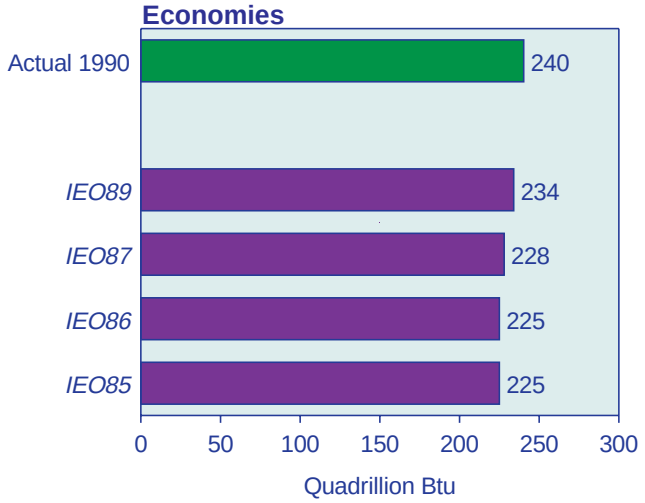
The regional aggregation has changed from report to report. In 1990, the report coverage was expanded for the first time from coverage of only the market economies to coverage of the entire world. Projections for China, the former Soviet Union, and other CPE countries were provided separately.

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 (no *IEO* was published in 1988) 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 1999* (Figure G1).

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 historical 1995 data (Figure G2). Most of the difference is attributed to those market economy countries outside the Organization for Economic Cooperation and Development (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.

IEO90 marked the first release of a worldwide energy consumption forecast. Since *IEO90*, the forecasts for worldwide energy demand have been between 2 and 5 percent higher than the actual amounts consumed (Figure G3). 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 this 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 1993 energy demand for

Figure G1. Comparison of *IEO* Forecasts with 1990 Energy Consumption in Market Economies



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *International Energy Outlook*, DOE/EIA-0484 (Washington, DC, various years).

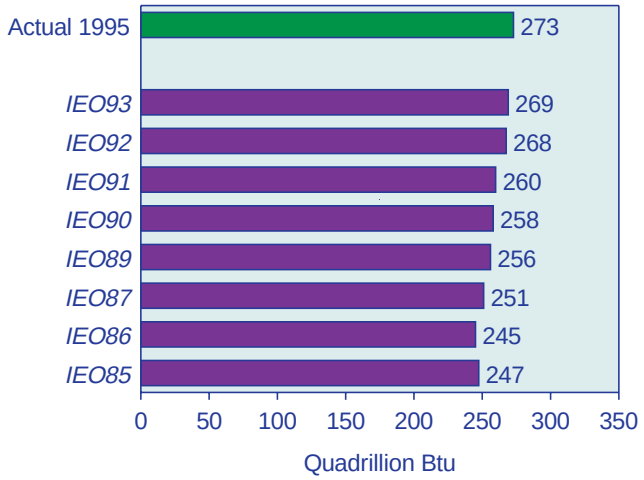
[39]Energy Information Administration, *International Energy Annual 1999*, DOE / EIA-0219(99) (Washington, DC, February 2001).

1995 in the FSU region was still projected to be 53 quadrillion Btu, as compared with actual 1995 energy consumption of 43 quadrillion Btu, some 10 quadrillion Btu (or about 5 million barrels of oil per day) less than projected in *IEO93*.

Considering the forecasts for the year 1995 strictly in terms of depicting future trends associated with the fuel mix, the *IEO* reports have performed well. Each *IEO* since 1990 has projected the fuel mix within 3.5 percentage points of the actual 1995 mix. The earliest *IEO*s tended to be too optimistic about the growth of coal use in the market economies[40] (Figure G4), and not optimistic enough 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 G5). 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.

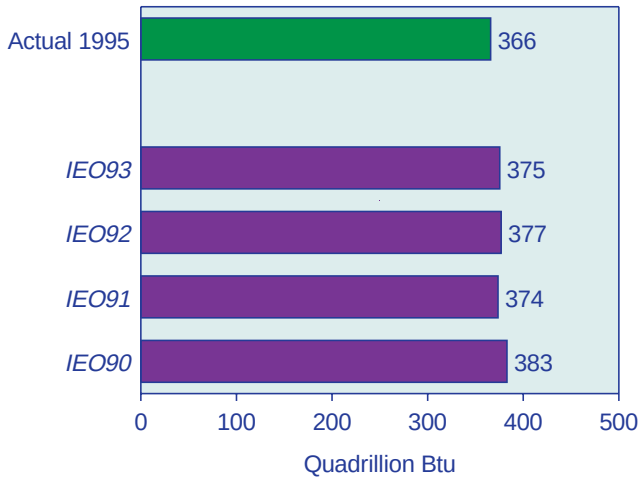
The forecasts for world coal consumption that appeared in the *IEO*s printed between 1990 and 1993 were consistently high, between 4 and 16 percent higher than actual coal use (Figure G6), largely because of overestimates for the former Soviet Union and Eastern Europe—regions that experienced substantial declines in coal consumption during the years following the collapse of the Soviet Union. Most of the by-fuel projections for the FSU were greater than the actual consumption numbers, with the exception of hydroelectricity and other renewable resources (Figure G7). 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, but even the *IEO* estimates for 1995 natural gas use were 16 to 22 percent higher than the actual use.

Figure G2. Comparison of *IEO* Forecasts with 1995 Energy Consumption in Market Economies



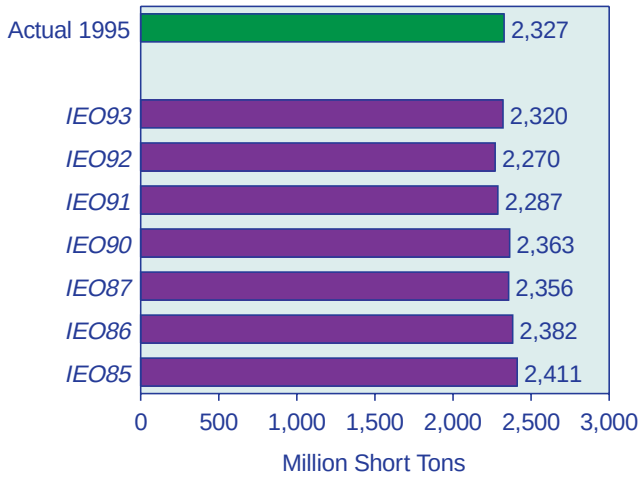
Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *International Energy Outlook*, DOE/EIA-0484 (Washington, DC, various years).

Figure G3. Comparison of *IEO* Forecasts with 1995 World Energy Consumption



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *International Energy Outlook*, DOE/EIA-0484 (Washington, DC, various years).

Figure G4. Comparison of *IEO* Forecasts with 1995 Coal Consumption in Market Economies



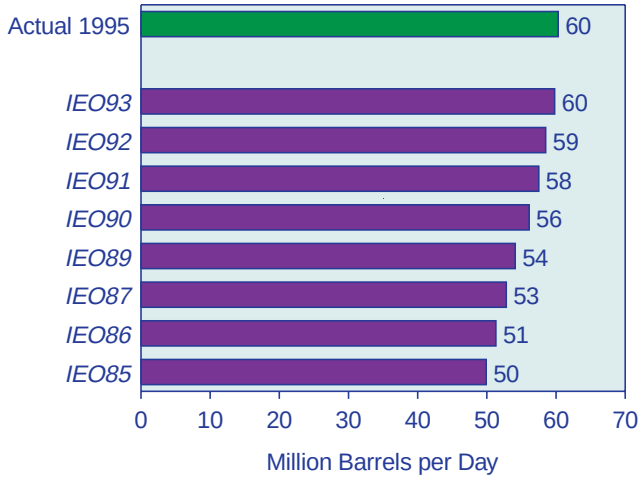
Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *International Energy Outlook*, DOE/EIA-0484 (Washington, DC, various years).

[40] Projections for West Germany and later unified Germany have been removed from the values considered here because of the lack of continuity in the coal data series after reunification.

The EIA 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 *IEO*s 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, EIA 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 G8). 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.

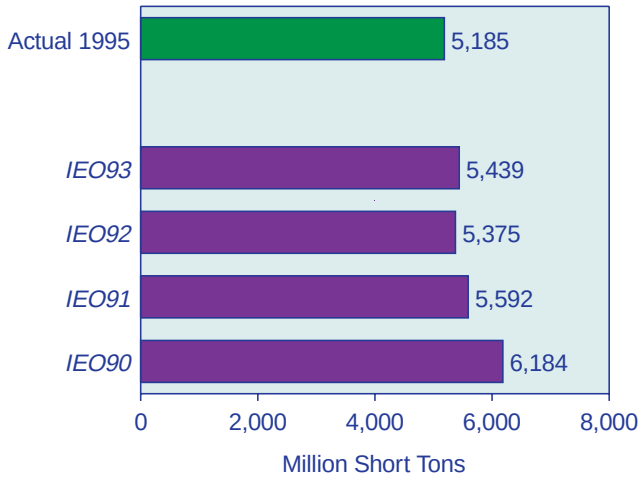
The comparison of *IEO* projections and historical data in the context of political and social events underscores the importance of these events in shaping the world's energy markets. Such comparisons also point out how important a model's assumptions are to the derivation of accurate forecasts. The political and social upheaval in

Figure G5. Comparison of *IEO* Forecasts with 1995 Oil Consumption in Market Economies



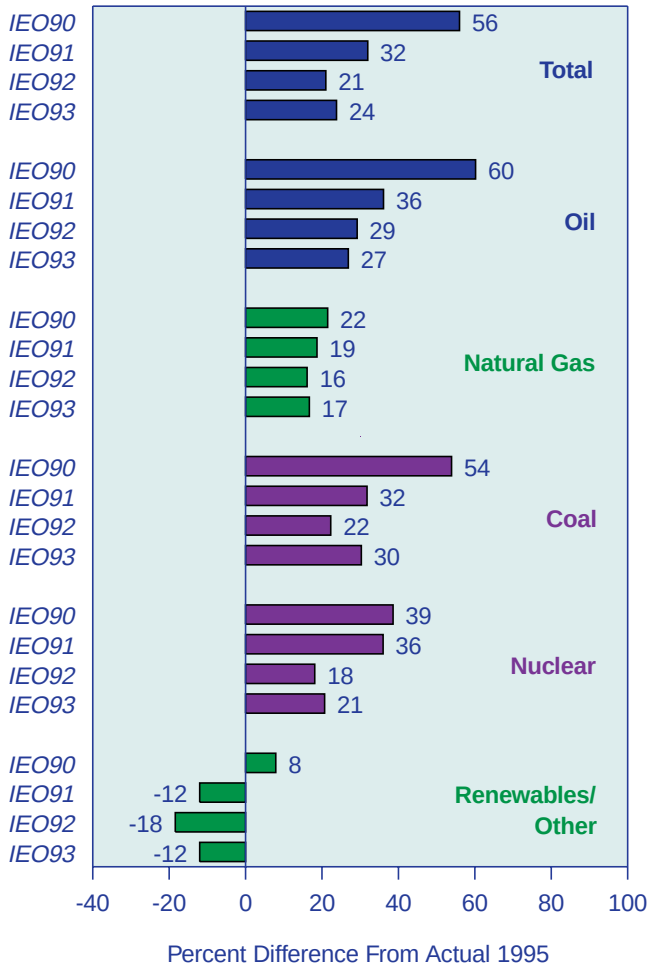
Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *International Energy Outlook*, DOE/EIA-0484 (Washington, DC, various years).

Figure G6. Comparison of *IEO* Forecasts with 1995 World Coal Consumption



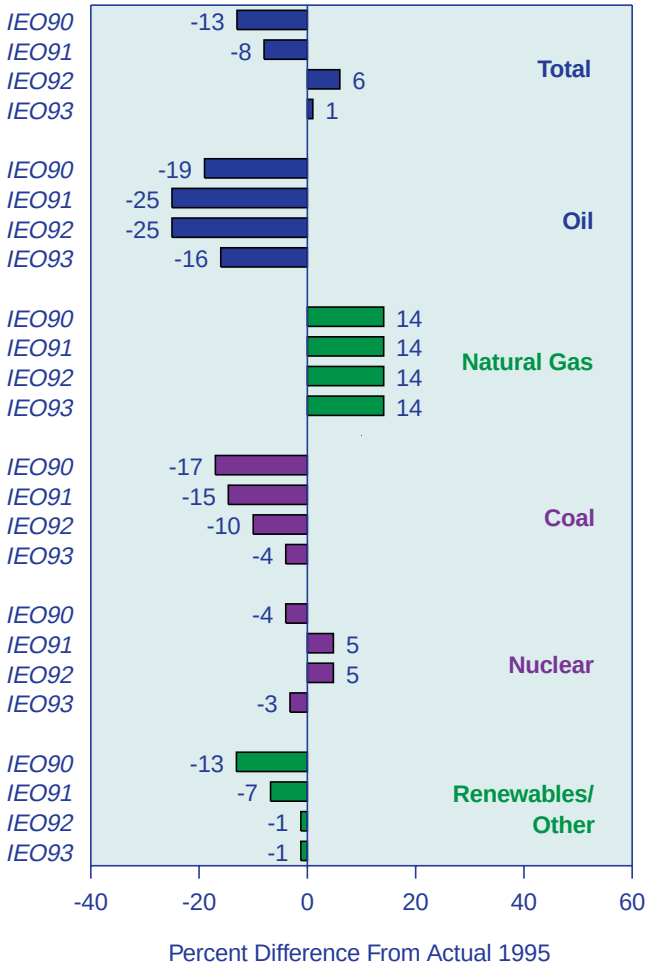
Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *International Energy Outlook*, DOE/EIA-0484 (Washington, DC, various years).

Figure G7. Comparison of *IEO* Forecasts with 1995 Energy Consumption in the Former Soviet Union by Fuel Type



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *International Energy Outlook*, DOE/EIA-0484 (Washington, DC, various years).

Figure G8. Comparison of *IEO* Forecasts with 1995 Energy Consumption in China by Fuel Type



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, *International Energy Outlook*, DOE/EIA-0484 (Washington, DC, various years).

Eastern Europe and the former Soviet Union was not predictable, and it 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.