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Electronic Access and Related Reports

The *IEO2001* will be available on CD-ROM and the EIA Home Page (*http://www.eia.doe.gov/oiaf/ieo/index.html*) by May 2001, including text, forecast tables, and graphics. To download the entire publication in Portable Document Format (PDF), go to *ftp://ftp.eia.doe.gov/pub/pdf/international/0484(2001).pdf*.

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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 2001 (IEO2001)* 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 2001* (*AEO2001*), which was prepared using the National Energy Modeling System (NEMS). U.S. projections appearing in the *IEO2001* are consistent with those published in the *AEO2001*. *IEO2001* 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 *IEO2001* projections are based on U.S. and foreign government policies in effect on October 1, 2000.

Projections in *IEO2001* are displayed according to six basic country groupings (Figure 1). The industrialized region includes projections for nine individual countries—the United States, Canada, Mexico, Japan, France, Germany, Italy, the Netherlands, and the United Kingdom—plus the subgroups Other Europe and Australasia (the latter defined as Australia, New Zealand, and the U.S. Territories). The developing countries are represented by four separate regional subgroups: developing Asia, Africa, Middle East, and Central and South America. China, 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 *IEO2001* 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 *IEO2001* 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 *IEO2001* 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 four alternative cases: high oil price, low oil price, high non-OPEC supply, and low non-OPEC supply. The projections were derived from WEPS and from the 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:

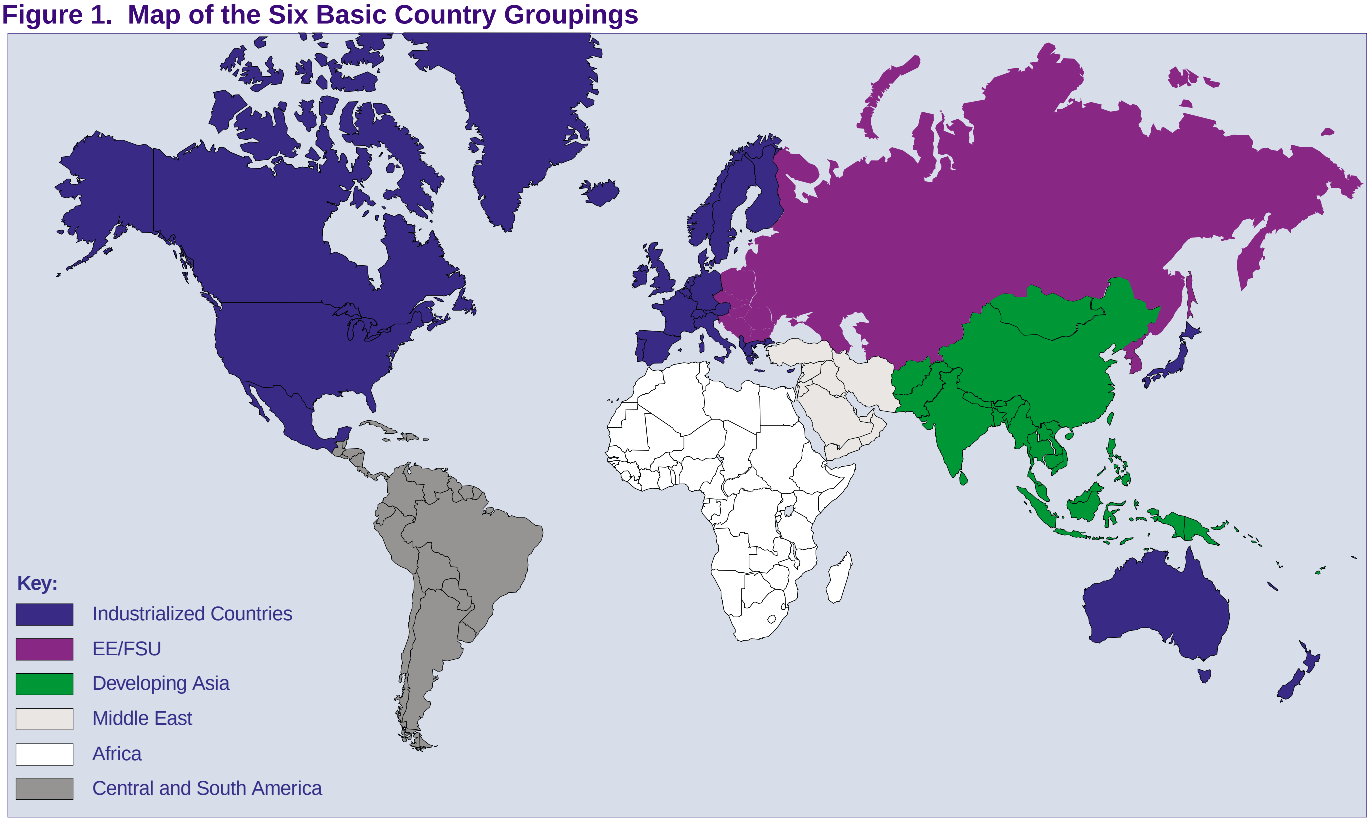
- **Industrialized Countries** (the industrialized countries contain 18 percent of the 2000 world population): Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and the United States.

- **Eastern Europe and the Former Soviet Union (EE/FSU)** (7 percent of the 2000 world population):
  - **Eastern Europe:** Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Hungary, Macedonia, Poland, Romania, Serbia and Montenegro, Slovakia, and Slovenia.
  - **Former Soviet Union:** Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Russia, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan.

- **Developing Asia** (54 percent of the 2000 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, Tuvalu, Vanuatu, and Vietnam.

- **Middle East** (4 percent of the 2000 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 2000 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 2000 world population): Antarctica, Antigua and Barbuda, Argentina, Aruba, Bahama Islands, Barbados, Belize, Bolivia, Brazil, British Virgin Islands, Cayman Islands, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, Falkland Islands, French Guiana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Montserrat, Netherlands Antilles, Nicaragua, Panama Republic, Paraguay, Peru, St. Kitts-Nevis, St. Lucia, St. Vincent/Grenadines, Suriname, Trinidad and Tobago, Uruguay, and Venezuela.

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

- **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, the United Kingdom, and the United States.[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, 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 *IEO2001* Projections

The projections in *IEO2001* 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.

Highlights

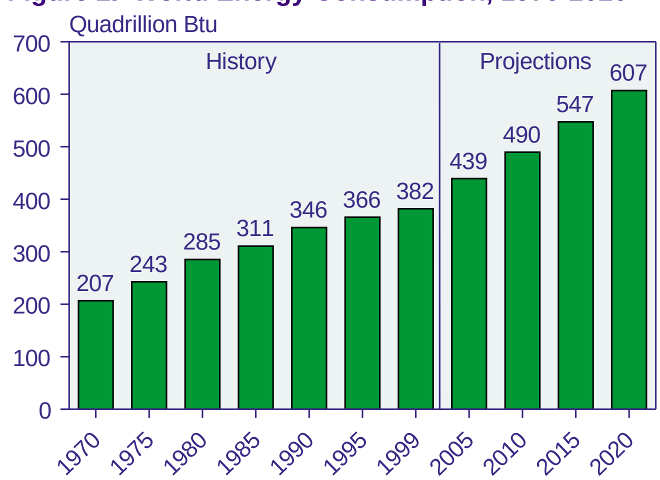
World energy consumption is projected to increase by 59 percent from 1999 to 2020. Much of the growth in worldwide energy use is expected in the developing world in the IEO2001 reference case forecast.

In the reference case projections for the *International Energy Outlook 2001* (*IEO2001*), world energy consumption is projected to increase by 59 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 607 quadrillion Btu in 2020 (Figure 2 and Table 1). Many developments in 2000 influenced this year's outlook, including persistently high world oil prices, stronger than anticipated economic recovery in southeast Asia, and robust economic growth in the former Soviet Union that has been sustained for two consecutive years—the first time this has occurred since the collapse of the Soviet regime.

Much of the growth in worldwide energy use is expected in the developing world in the reference case forecast (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 more than one-half of the total projected increment in world energy consumption and 81 percent of the increment for the developing world alone.

World oil prices have been extremely volatile for the past 3 years (Figure 4). In 1998, consumers benefited from oil prices that fell to $10 per barrel—a result of oversupply caused by lower demand for oil both in southeast Asia, which was suffering from an economic recession, and in North America and Western Europe because of warmer than expected winters. In 2000, however, world oil prices rebounded strongly, reaching a daily peak of $37 per barrel, rates not seen since the Persian Gulf War of 1990-1991. The high prices can be traced to a tightening of production by the Organization of Petroleum Exporting Countries (OPEC) and several key non-OPEC countries (Russia, Mexico, Oman, and Norway) and a reluctance by oil companies to commit capital to major development efforts for fear of a return

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, January 2001). **Projections:** EIA, World Energy Projection System (2001).

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

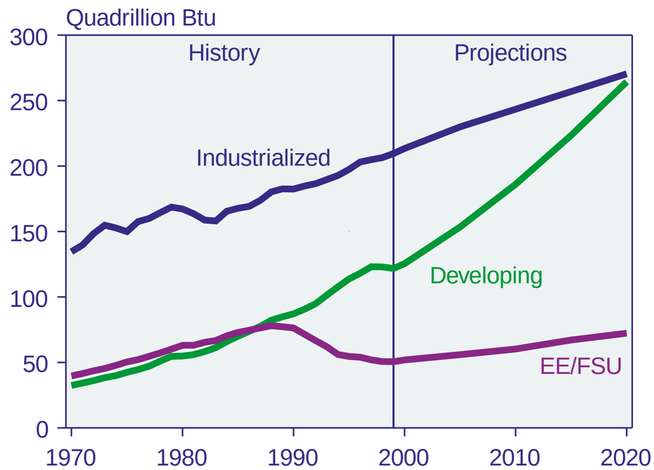
Region	Energy Consumption (Quadrillion Btu)				Carbon Dioxide Emissions (Million Metric Tons Carbon Equivalent)			
	1990	1999	2010	2020	1990	1999	2010	2020
Industrialized	**182.4**	**209.6**	**243.4**	**270.4**	**2,842**	**3,122**	**3,619**	**4,043**
EE/FSU	**76.3**	**50.5**	**60.3**	**72.3**	**1,337**	**810**	**940**	**1,094**
Developing								
Asia	51.0	70.9	113.4	162.2	1,053	1,361	2,137	3,013
Middle East	13.1	19.3	26.9	37.2	231	330	451	627
Africa	9.3	11.8	16.1	20.8	179	218	294	373
Central and South America	13.7	19.8	29.6	44.1	178	249	394	611
Total	**87.2**	**121.8**	**186.1**	**264.4**	**1,641**	**2,158**	**3,276**	**4,624**
Total World	**346.0**	**381.8**	**489.7**	**607.1**	**5,821**	**6,091**	**7,835**	**9,762**

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

to low prices, in concert with unexpectedly strong demand recovery in the recovering economies of Asia. Unrest in the Middle East has also exacerbated the price volatility. Oil companies were also reluctant to refill abnormally low stock levels, because they feared a return to the low price environment of 1998.

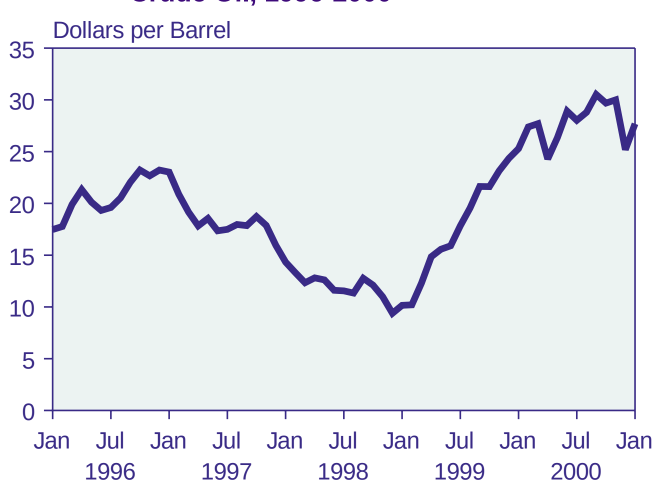
The *IEO2001* reference case expects world oil prices to increase from $17.35 per barrel in 1999 (1999 dollars) to about $27.60 in 2000, then fall to $20.50 per barrel by 2003 and return to the price trajectory anticipated in last year's outlook for the mid-term. World oil prices are expected to reach $22 per barrel in 1999 dollars ($36 per barrel in nominal dollars) at the end of the projection period—about the same as in last year's forecast (Figure 5).

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, January 2001). **Projections:** EIA, World Energy Projection System (2001).

Figure 4. Refiner Acquisition Cost of Imported Crude Oil, 1996-2000

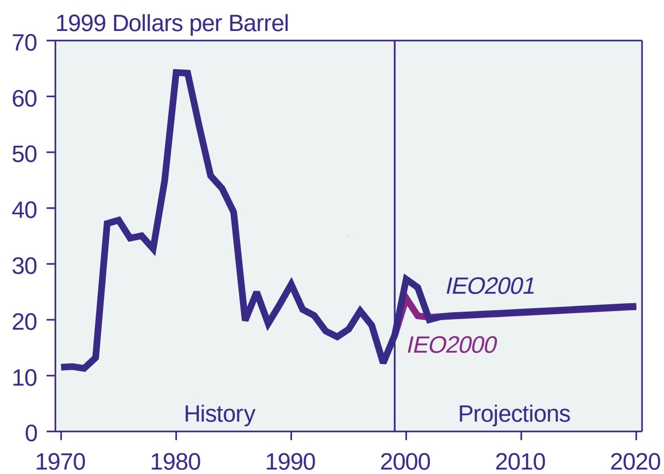


Source: Energy Information Administration, "Crude Oil Price Summary," MER Spreadsheet, Table 9.1, web site www.eia.doe.gov/emeu/mer/prices (October 2000).

High world oil prices and improved domestic industrial production helped Russia, the largest economy in the former Soviet Union (FSU), to record two consecutive years of positive economic growth for the first time since the breakup of the Soviet Union in the early 1990s. The collapse of the Russian ruble in 1998 led to a boost in industrial production as it became too expensive to import goods from abroad. Russian industrial output experienced double digit growth through much of 2000; and production increases, supplemented by the revenues obtained in the high oil price environment, allowed the Russian economy to advance strongly in 1999 and 2000. The improved economic outlook for Russia and the rest of the FSU is expected to result in energy demand growth for the region of 1.7 percent per year between 1999 and 2020, reaching 56 quadrillion Btu at the end of the forecast.

The industrialized world also was affected by the high world oil price environment of 2000. Concerns in the United States about a recurrence of the previous winter's shortage of home heating fuel oil for the Northeast—given the very low stock levels of August 2000—led the Clinton Administration to allow industry access to as much as 30 million barrels of crude oil from the Nation's Strategic Petroleum Reserve. Within the European Union, member countries Spain and France

Figure 5. Comparison of 2000 and 2001 World Oil Price Projections



Sources: **History:** Energy Information Administration (EIA), *Annual Energy Review 1999*, DOE/EIA-0384(99) (Washington, DC, July 2000). ***IEO2000:*** EIA, *International Energy Outlook 2000*, DOE/EIA-0484(2000) (Washington, DC, March 2000). ***IEO2001:*** 1999-2002—EIA, *Short-Term Energy Outlook*, on-line version (February 7, 2001), web site www.eia.doe.gov/emeu/steo/pub/contents.html. 2003-2020—EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000).

expressed the desire to follow the U.S. lead, but the International Energy Agency, United Kingdom, and Germany opposed the move, and the stocks ultimately were not released. Multiple strikes to protest high fuel prices were launched or threatened throughout Western Europe in the third quarter of 2000 by truckers, farmers, and taxi drivers (whose livelihood is immediately affected by the cost of fuel), expressing consumer anger that is rarely seen in the ordinarily high fuel cost environment of that region.

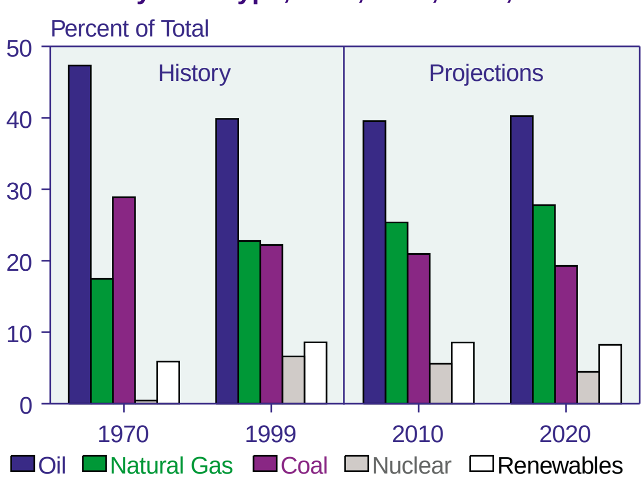
Worldwide, oil consumption rose by slightly less than 1 million barrels per day in 2000, with nonindustrialized nations accounting for all of increase and, of that, Pacific Rim countries and China responsible for about 50 percent. The increases in worldwide oil demand projected in the reference case would require an increment of 43 million barrels per day relative to 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 and deepwater West Africa. Deepwater exploration and development initiatives are generally expected to be sustained worldwide, with offshore West Africa emerging as a major future source of oil production. 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.

Oil currently provides a larger share of world energy consumption than any other energy source, and it is expected to remain in that position through 2020 (Figure 6). The share of total world energy consumption attributed to oil is projected to remain unchanged over the 1999-2020 time period at 40 percent. Oil's market share does not increase in the forecast because countries in many parts of the world are expected to switch to natural gas and other fuels, particularly for electricity generation. World oil consumption is projected to increase by 2.3 percent annually over the 21-year projection period, from 75 million barrels per day in 1999 to 120 million barrels per day in 2020.

The industrialized countries continue to consume more of the world's petroleum products than do the developing countries, but the gap is projected to close substantially over the projection period. By 2020, developing countries are expected to consume almost the same amount of oil as the industrialized countries (Figure 7). Almost all the increase in oil use in the industrialized world is expected to occur in the transportation sector, where there are few economically competitive alternatives to oil currently available. In the developing world, however, oil demand is projected to grow in all end use sectors as emerging economies shift from noncommercial fuels (such as fuel wood for home heating and cooking) to diesel generators.

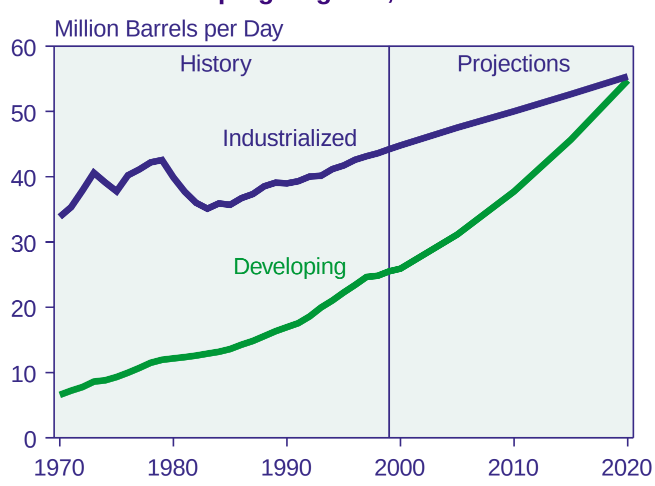
Natural gas remains the fastest growing component of primary world energy consumption. Over the *IEO2001* forecast period, gas use is projected to nearly double in the reference case, reaching 162 trillion cubic feet in 2020. Gas use surpassed coal use (on a Btu basis) for the first time in 1999, and by 2020 it is expected to exceed coal use by 44 percent (Figure 8). The gas share of total energy

Figure 6. World Energy Consumption Shares by Fuel Type, 1970, 1999, 2010, and 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, January 2001). **Projections:** EIA, World Energy Projection System (2001).

Figure 7. Oil Consumption in the Industrialized and Developing Regions, 1970-2020



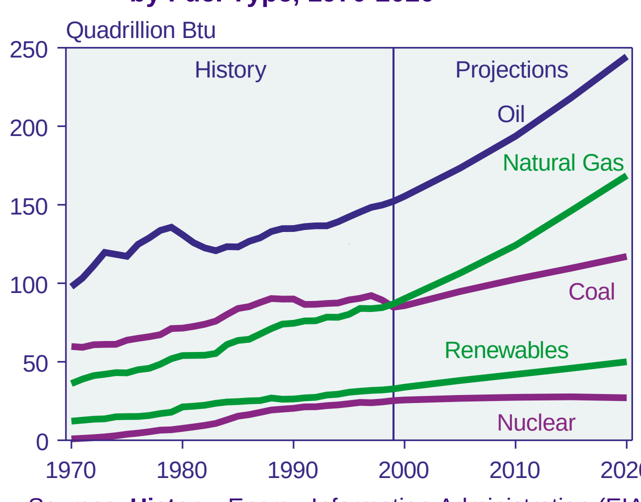
Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, World Energy Projection System (2001).

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 32 quadrillion Btu or 41 percent of the total increment in energy used for electricity generation). Combined-cycle gas turbine power plants offer some of the highest commercially available plant efficiencies, and natural gas is environmentally attractive because it emits less sulfur dioxide, carbon dioxide, and particulate matter than does oil or coal.

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 other uses, including fuel for industry. Gas use in the developing world is projected to grow at a faster rate than any other fuel category in the *IEO2001* reference case, an average of 5.2 percent per year, compared to 3.7 percent per year for oil and 3.1 percent for coal.

Coal's share of total energy consumption is projected to fall slightly in the *IEO2001* reference case, from 22 percent in 1999 to 19 percent in 2020 (Figure 6). Only a slight loss from its historical share is expected, because large increases in energy use are projected for the developing countries of Asia, especially China and India, which rely heavily on coal and have significant coal resources. As very large countries in terms of both population and land mass, China and India are projected to account for 30 percent of the world's total increase in energy

Figure 8. 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, January 2001). **Projections:** EIA, World Energy Projection System (2001).

consumption over the forecast period, and the expected increases in coal use in China and India are projected to account for 92 percent of the total expected increase in coal use worldwide (on a Btu basis). Almost 60 percent of the coal consumed worldwide is used for electricity generation, and virtually all of the projected growth in the world's consumption of coal is for electricity. 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 alternative sources of energy.

The prospects for nuclear power to continue its role of meeting a significant share of worldwide electricity consumption are uncertain, despite projected growth of 2.7 percent per year in total electricity demand through 2020. In the *IEO2001* reference case, worldwide nuclear capacity is projected to increase to 365 gigawatts in 2010, then begin to decline, falling to 351 gigawatts in 2020. Most of the growth in nuclear capacity is expected to occur in the developing world (particularly in developing Asia), where consumption of electricity generated from nuclear plants is projected to increase by 4.9 percent per year between 1999 and 2020. In contrast, older reactors are expected to be retired in the industrialized world and the EE/FSU, and few new reactors are planned to replace them. Exceptions include France and Japan, where several new reactors are expected to begin operating in the next decade or so.

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 to 8 percent by 2020. Although energy prices reached record high levels in 2000, the *IEO2001* reference case projection expects energy prices over the long term to remain relatively low, constraining the expansion of hydroelectricity and other renewable resources. Much of the growth in renewable energy use in the *IEO2001* reference case is attributable to large-scale hydroelectric projects in the developing world, particularly in developing Asia, where China, India, and other developing Asian nations (Nepal and Malaysia among others) already are building or planning to build hydroelectric projects that exceed 1,000 megawatts. Hydroelectricity and other renewable energy consumption is projected to grow by 4.0 percent per year in developing Asia over the projection period, with particularly strong growth projected for China.

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 the developing world. The most rapid expansion in electricity use in the reference case is expected for developing Asia and Central and South

America, with average annual growth rates exceeding 3.5 percent between 1999 and 2020 (Figure 9). 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 washers and dryers) 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 modulate that trend in the future.

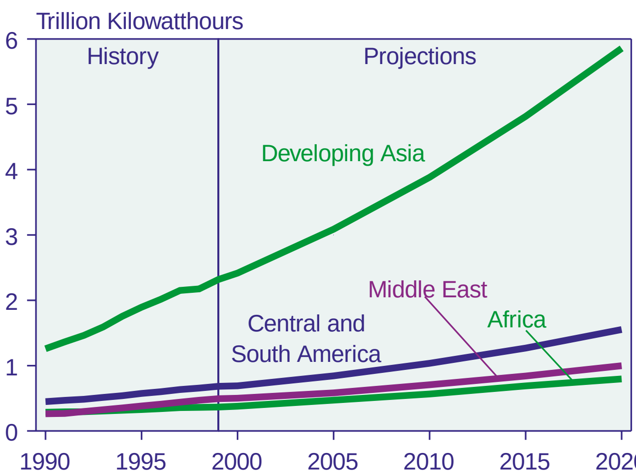
In the United States, electricity prices increased sharply in California, New York, and several other States in the summer of 2000. In California, San Jose and San Francisco experienced rolling blackouts, and customers of San Diego Gas and Electric saw their bills triple. California's implementation of deregulation and inadequate new generating capacity were blamed for the price spikes. Nevertheless, the trend to consolidate the U.S. electricity industry continues. Consolidation has occurred through the sale of individual electricity assets, particularly generation assets. For the first time in the United States, nuclear generation assets have changed ownership. A recent development is the purchase of U.S. electric utility plants by foreign companies, primarily by a handful of companies from the United Kingdom but also including some Japanese companies and at least one French company.

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 *IEO2001* reference case, energy use for transportation is projected to increase by 4.8 percent per year in the developing world, compared with average annual increases of 1.6 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 10).

Global climate change—one of the most wide-reaching environmental issues of recent years—serves as a prime example of the divergent concerns of energy and the environment. Carbon dioxide emissions resulting from the combustion of fossil fuels currently are estimated to account for three-fourths of human-caused carbon dioxide emissions worldwide and are believed to be contributing to the rise in atmospheric concentrations of carbon dioxide since pre-industrial times. World carbon dioxide emissions are projected to rise from 6.1 billion metric tons carbon equivalent in 1999 to 7.8 billion metric tons

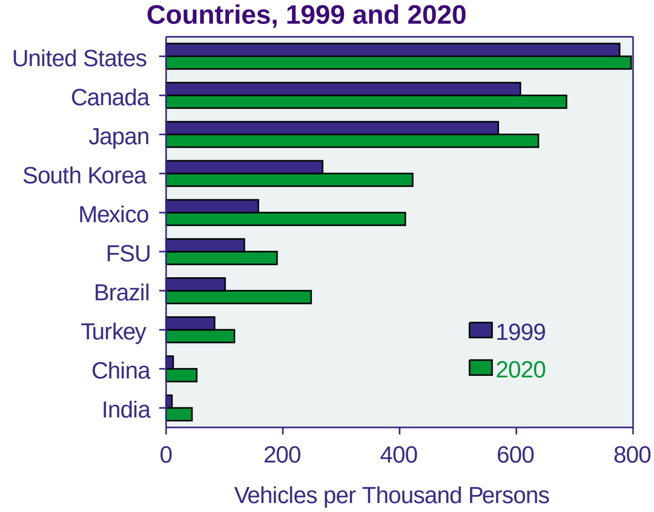
Figure 9. Net Electricity Consumption in the Developing World by Region, 1990-2020



Note: Net electricity consumption is equal to generation plus imports minus exports and distribution losses.

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

Figure 10. Motorization Levels in Selected Countries, 1999 and 2020



Source: Energy Information Administration, World Energy Projection System (2001).

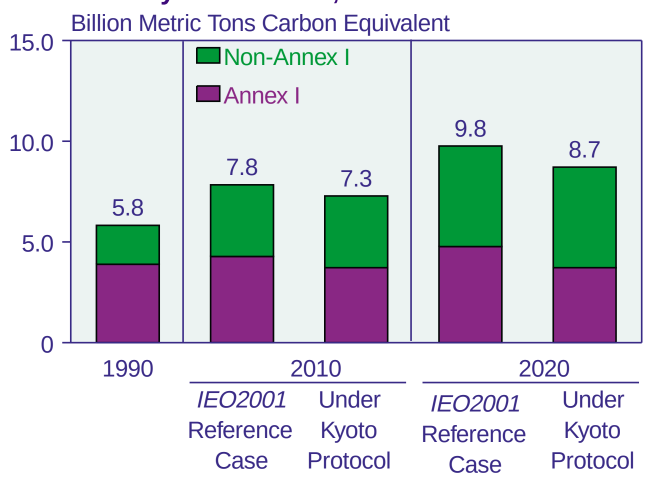
per year in 2010 and to 9.8 billion metric tons in 2020 (Table 1). The *IEO2001* projections are based on current laws and regulations and do not take into account the potential impact of policies that might be enacted to limit or reduce carbon dioxide emissions, such as the Kyoto Protocol, which if signed by the required number of signatories would require all signatories to reduce or limit carbon dioxide emissions relative to their 1990 levels between 2008 and 2012.

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 81 percent of the projected increment in carbon dioxide emissions between 1990 and 2010 and 76 percent between 1990 and 2020. Continued heavy reliance on coal and other fossil fuels, as projected for the developing countries, would ensure that even if the industrialized world undertook efforts to reduce carbon dioxide emissions, worldwide carbon dioxide emissions would still grow substantially over the forecast horizon (Figure 11).

The *IEO2001* 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.

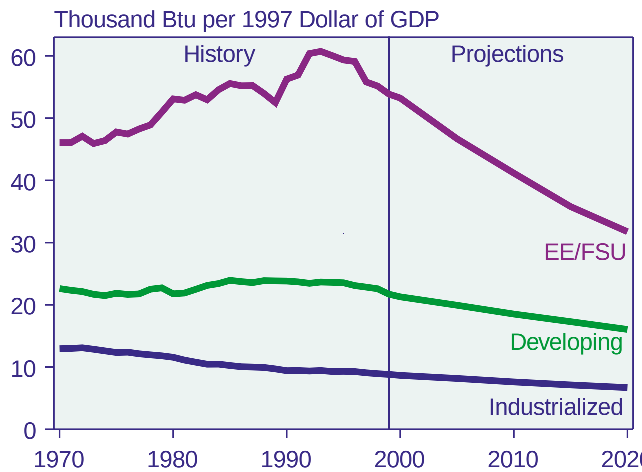
In the *IEO2001* forecast, energy intensity in the industrialized countries is expected to improve (decrease) by 1.3 percent per year between 1999 and 2020, about the same rate of improvement observed in the region between 1970 and 1999. Energy intensity is also projected to improve in the developing countries—by 1.4 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 12). The EE/FSU has always 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.

Figure 11. World Carbon Dioxide Emissions in the *IEO2001* Reference Case and Under the Kyoto Protocol, 2010 and 2020



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

Figure 12. 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, January 2001). **Projections:** EIA, World Energy Projection System (2001).

World Energy Consumption

The IEO2001 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 2001* (*IEO2001*) 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 *IEO2001* 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 *IEO2001* projections and how future energy intensity trends could influence the reference case projections. The chapter ends with a comparison of the *IEO2001* projections with forecasts available from other organizations.

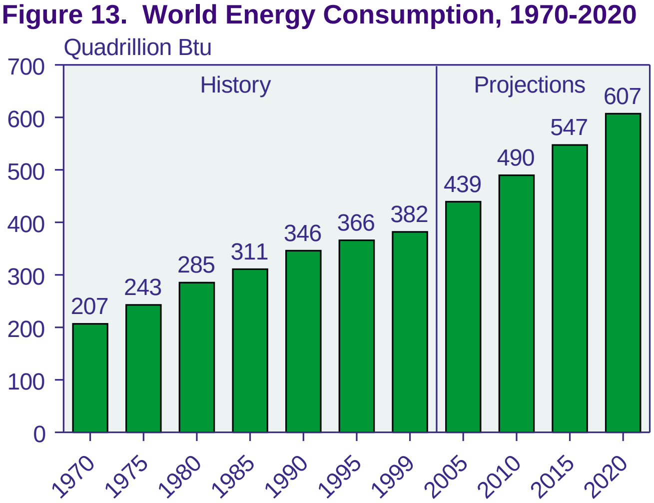
Current Trends in World Energy Demand

In the *International Energy Outlook 2001* (*IEO2001*) reference case, world energy consumption is projected to rise by 59 percent between 1999 and 2020, reaching 607 quadrillion British thermal units (Btu) at the end of the forecast (Figure 13). This projection is similar to last year's forecast, despite the high world oil price environment that largely defined 2000, stronger than anticipated economic recovery in southeast Asia, and positive economic growth in the former Soviet Union that has been sustained for 2 years—the first time this has occurred since the dissolution of the Soviet Union.

As in past *IEO*s, the highest growth in energy consumption over the projection period is expected in the developing countries, particularly those of developing Asia and Central and South America (Figure 14). Much of the projected increase in energy use in the developing world is attributed to expectations for strong economic growth accompanied by higher standards of living and new demand for personal motorization, home appliances, cooking, space heating, and cooling services.

The energy markets of the past year have been strongly influenced by trends in world oil prices, which have been extremely volatile for the past 3 years (Figure 15). Consumers enjoyed oil prices that slipped to $10 per barrel in 1998, with oversupply caused by lowered worldwide demand resulting from the Asian economic recession that began in the spring of 1997, increases in oil exports from Iraq, and warmer than expected winters in North America and Western Europe. Since then, world oil prices have more than tripled, reaching a daily peak of $37 per barrel, rates not seen since the Persian Gulf

Figure 13. World Energy Consumption, 1970-2020

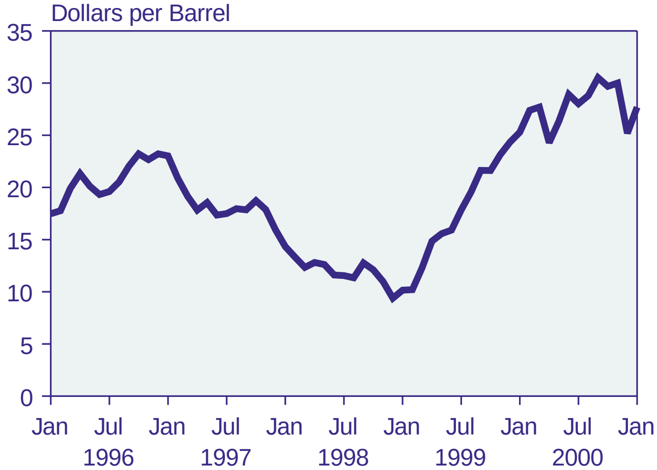


Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, World Energy Projection System (2001).

Figure 14. Projected Change in Energy Demand by Region, 1999-2020

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

Figure 15. Refiner Acquisition Cost of Imported Crude Oil, 1996-2000



Source: Energy Information Administration, "Crude Oil Price Summary," MER Spreadsheet, Table 9.1, web site www.eia.doe.gov/emeu/mer/prices (October 2000).

War of 1990-1991. The high prices can be traced to a tightening of production by OPEC member countries and several non-OPEC countries (Russia, Mexico, Oman, and Norway) and to the unexpectedly strong demand for oil in the recovering economies of southeast Asia. Unrest in the Middle East has exacerbated the price volatility.

By mid-2000, after several months of oil prices in excess of $30 per barrel, OPEC member Saudi Arabia announced a desire to bring oil prices to an "optimal range" of $22 to $28 per barrel—a price level that would give oil producers reasonable compensation without adversely affecting the economic growth of oil-consuming countries worldwide. Because prices remained above this range for much of the first half of 2000, OPEC members at their June 2000 meeting pledged production increases of 708 thousand barrels per day beginning in July 2000. EIA estimated that only Saudi Arabia, Kuwait, and, to a lesser degree, the United Arab Emirates would have the productive capacity to provide the additional supplies [***1***].

The increased supply pledged by OPEC had little or no impact on world oil prices, and in July, Saudi Arabia announced that to bring the OPEC basket price down to $25 per barrel, the country would increase crude oil supplies by another 500 thousand barrels per day if oil prices remained high [***2***]. On September 10, 2000, OPEC met again and announced further production quota increases of 800 thousand barrels per day beginning in October. However, analysts voiced concerns about the stability of Iraqi supply, given a sharp drop in production in June 2000 [***3***]. In mid-September 2000, Iraqi President Saddam Hussein asked other OPEC member countries not to increase production and also accused Kuwait of producing oil from Iraqi oil fields.

Concerns in the United States about a potential shortage of home heating fuel oil for the Northeast—given the very low stock levels of August 2000—led to the September 22 decision by the Clinton Administration to allow industry access to as much as 30 million barrels of crude oil from the Nation's Strategic Petroleum Reserve (SPR). Oil prices fell from $33 per barrel to about $30 per barrel immediately after the announcement.

European Union (EU) member countries Spain and France signaled a desire to follow the U.S. lead and release their government-owned oil reserves (in the EU many member countries are required to maintain 90 days of oil supply reserves) to bring down prices in the short run, but the International Energy Agency (IEA), United Kingdom, and Germany stated their opposition to such a move, believing that government stocks should be used only for emergency purposes and not to manipulate prices [***4***]. A release of Europe's emergency stocks cannot occur without IEA approval.

Many European countries witnessed growing consumer anger over high motor fuel prices in the third quarter of 2000. European consumers are not generally sensitive to changes in motor vehicle fuel prices—particularly relative to U.S. consumers—because motor fuels are often subject to much higher taxation rates than in the United States [***5***]. Taxes make up more than 50 percent of the retail price for motor gasoline in most European countries. With crude oil prices hovering at $37 per barrel in September, truckers and farmers in France staged a strike demanding that the government reduce taxes on diesel fuel, arguing that high prices were making it impossible for their businesses to be profitable. After 3 weeks, the French government agreed to reduce fuel prices for farmers and truckers by 15 percent. Strikes quickly spread to other European countries, including Belgium, Germany, Italy, the Netherlands, and the United Kingdom, with additional strikes launched or threatened in Norway, Spain, Sweden, Greece, and Ireland.

The strike in the United Kingdom was particularly dramatic. Truckers and taxi cab drivers blockaded oil refineries throughout the country. More than 90 percent of the country's gasoline stations were reporting shortages or ran out of fuel altogether as panic buying occurred and refinery tanker drivers were unable or unwilling to risk attempts to deliver new supply in the atmosphere of the week-long strike. The protesters were demanding tax reductions in a country that currently has the highest tax burden on motor fuels in Western Europe. About 75 percent of the price of motor gasoline in the United Kingdom is federal tax. While the Blair Administration refused to reduce the taxes, at the end of the first week of the strike government officials conceded a willingness to look at reducing—or at least not increasing—motor fuel taxes in their next budget talks.

Fuel price protests eventually spread to several Eastern European countries, including Poland, Slovenia, and the Czech Republic and even beyond the European continent. In late September, in the wake of a political bribery scandal that forced Peru's President Fujimori to call for new presidential elections, political tensions and high fuel prices prompted a strike by truckers and bus drivers similar to those staged in Europe. The strikers disrupted port activity, which all but stopped Peruvian exports. In one week, exports fell by an estimated 95 percent according to the Peruvian National Ports Office [*6*]. Protesters demanded that the government reduce fuel taxes by 42 percent and lower highway tolls, even though world oil prices fell by nearly 20 percent during the 10-day strike.

In Asia, both Indonesia and Malaysia—both net oil exporters—have raised motor gasoline prices because of the high oil price environment. Thousands of Indonesians turned out to protest the one-day-old price hike in October 2000, and increasing social unrest threatens to unhinge the country's efforts to recover from the political and economic crisis of 1997-1999 [*7*]. Malaysia did raise motor gasoline prices in 1999, by between 20 and 40 cents per gallon, but this represented the first increase in gasoline prices since 1983, and Malaysian consumers will still only pay between $1.30 and $1.50 cents per gallon for their fuel [*8*]. Car sales in Malaysia have been increasing at a rapid pace (by 23 percent between 1999 and 2000 alone), and it is difficult to imagine that the demand for transportation fuels will decline as a result of the increase in gasoline prices.

The recent developments outlined above underscore the importance of world oil markets in today's global economy. It was largely the economic crisis in Asia that led to surplus oil supply in 1998, and the region's stronger than anticipated economic growth and accompanying growth in oil demand were in part responsible for the oil supply deficits in 2000. The countries of southeast Asia have recovered much more quickly from their 1997-1999 recession than most analysts predicted. EIA's *Short-Term Energy Outlook* estimated that oil demand in developing Asia (excluding China, but including India and South Korea) grew by about 400 thousand barrels per day between 1999 and 2000, after falling by 300 thousand barrels per day between 1997 and 1998 and increasing by only 100 thousand barrels per day between 1998 and 1999 [*9*]. In China, oil demand has grown steadily by 200 thousand barrels per day each year between 1997 and 2000.

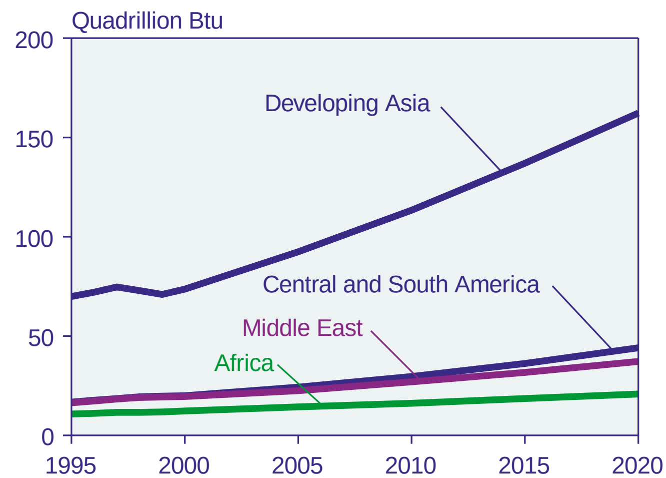
In the *IEO2001* reference case projections, developing Asia and Central and South America are expected to have the most rapid growth rates in energy demand over the next two decades (Figure 16). In both regions, total energy demand is expected to grow by about 4 percent per year between 1999 and 2020. All the southeast Asian countries that suffered from the "Asian flu" of 1997-1999 had positive economic growth rates in 2000—even Indonesia, where political and social unrest threatened economic recovery in 1999. High oil prices went a long way toward improving the Indonesian economy in 2000 and were in large part responsible for the country's record high $2.9 billion trade surplus in July 2000 [*10*].

Brazil, with Central and South America's largest economy, has recovered from the 1999 devaluation of the real, which sent the country into recession. The country's GDP grew by only 0.8 percent in 1999. The recession was not as deep or prolonged as many analysts had feared it would be, however, and the quick recovery in Brazil, the region's major consumer, has helped keep other countries in the region from faltering badly. Between June 1999 and June 2000, automobile sales in Brazil improved by 17 percent, and automobile exports improved by 53 percent [*11*].

In 2000, economic growth in Brazil, and indeed in Central and South America as a whole, was tempered by high world oil prices and low commodity prices. Almost all the countries in the region, with the exception of Argentina and Uruguay, posted positive economic growth rates for 2000, although the recovery in most cases was dampened by sustained high world oil prices. The exception is Venezuela, the region's major oil-exporting country, where economic expansion was particularly strong in 2000. Venezuela's oil exports totaled $2.2 billion dollars in May 2000, an 88-percent increase relative to May 1999 [*12*].

High world oil prices and improved domestic industrial production have helped Russia, the largest economy in

Figure 16. Energy Consumption in the Developing World by Region, 1995-2020



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

the former Soviet Union, record two consecutive years of positive economic growth for the first time since the breakup of the Soviet Union in the early 1990s. As a result of the collapse of the ruble in August 1998, domestically produced goods became competitive in international markets, and when imports collapsed, Russian consumers turned to domestic sources to meet their needs.

Russia's industrial output increased by an estimated 10.3 percent between January and June 2000, higher than in 1999 [***13***]. The production increases, supplemented by the revenues obtained in the high oil price environment of the previous year, allowed Russia's economy to grow by 3.2 percent in 1999 and an estimated 5.0 percent in 2000.

Until 2000, the region's second largest economy, Ukraine, had not recorded a year of positive economic growth in the post-Soviet era. However, 1999 produced the smallest contraction experienced by the country since its independence in 1991, and in 2000 its GDP grew by an estimated 3 percent [***14***]. Most of the growth is attributed to exports, industrial output, and improved domestic demand [***15***]. As in Russia, the weakness of the Ukrainian currency, the hryvnia, has benefited industrial production by increasing the competitiveness of Ukrainian goods in international markets. Exports were up by 24 percent in the first half of 2000.

The improvement in economic circumstances in the former Soviet Union is expected to result in energy demand growth for the region of 1.7 percent per year between 1999 and 2020, reaching 56 quadrillion Btu at the end of the forecast (but still 9 percent lower than the region's 1990 level of consumption). Between 1990 and 1994, energy use in the FSU fell by an average of 4 quadrillion Btu in each year (an average drop of between 6 and 11 percent per year); however, the rate of decline has for the most part leveled out in recent years. In 1999 the region's total energy use increased by 0.5 quadrillion Btu, perhaps signaling the end of a decade-long decline. The *IEO2001* reference case projects that energy use in the FSU will grow by 42 percent between 1999 and 2020, as compared with the 36-percent loss in demand between 1990 and 1999.

In contrast to the FSU, Eastern Europe began to enjoy measurable economic recovery soon after the fall of the Soviet Union. The region as a whole began to experience sustained positive economic growth after 1993, although the growth was slower between 1996 and 1999. Several developments led to the 1996-1999 economic slowdown in Eastern Europe. First, there were substantial downturns in two of the region's key economies, the Czech Republic and Romania. Moreover, Western European demand for East European goods was weaker because of economic recession in several key countries. Finally, the Eastern European economies felt the impact of the Russian and Ukrainian economic crises after the devaluation of the ruble in 1998, as well as the effects of government fiscal austerity programs that were put into place to deal with trade and payment imbalances [***16***].

The economic downturn in the Czech Republic was the result of a growing imbalance between trade and payments that required tightened fiscal policies [***17***]. In Romania, limited economic reforms and tight monetary policies aimed at restoring macroeconomic stability caused a series of sharp economic downturns in the 1997-1999 period [***18***]. All the countries in the region showed positive GDP growth in 2000. By 2020, energy consumption in Eastern Europe is projected to be almost 8 percent above the region's 1990 level.

North America's GDP growth remained robust in 2000, at an estimated 5.2 percent for the United States, 4.7 percent for Canada, and 5.6 percent for Mexico. In the short run, high world oil prices and high natural gas prices are expected to force a slowdown of the U.S. economy and increase inflation rates. Further, because of the interdependence of the economies that make up the North American Free Trade Agreement (NAFTA), the slowdown of the U.S. economy is virtually guaranteed to slow the growth of the economies of the two other member nations.

In the United States, oil consumption in 2000 was only 0.2 percent higher than in 1999. EIA's *Short-Term Energy Outlook* expects demand growth to average 1.9 percent in 2001, with the assumption that world oil prices will remain near $30 per barrel through 2001 and then drift downward, falling by perhaps a dollar per barrel between 2001 and 2002 [***19***]. In the long term, oil demand is projected to increase by 1.5 percent per year in North America as a whole, with particularly strong growth of 3.7 percent per year in Mexico.

In 2000, the European Union's currency, the euro, faced a difficult year as its value plunged to a low of $0.84 from highs of about $1.20 when it was first released in January 1999 [***20***]. In late September 2000, the International Monetary Fund convinced several international banks, including the European Central Bank, the Bank of Japan, and the U.S. Federal Reserve, to bolster euro exchange rates and attempt to control inflation through the purchase of as much as £5.5 billion worth of euros (about 7.9 billion U.S. dollars). The euro is scheduled to become the single currency of the 11 members of the European Union (Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxemburg, the Netherlands, Portugal, and Spain) by January 1, 2002, when actual euro notes and coins are to be issued [***21***]. The euro has suffered several disappointments, however, including Denmark's rejection of the referendum on adopting the euro in late September 2000 given its weak performance in 2000.

Sweden and the United Kingdom are slated to hold referenda on euro membership, but neither country has yet set a date for the voting.

The weakness of the euro bolstered exports from EU member countries by making European goods cheaper in outside markets and reducing the competitiveness of goods from the United States and Japan in European markets. That said, the performance of the euro relative to the yen and the dollar has contributed, along with high world oil prices, to inflation levels exceeding the European Central Bank's limit of 2.4 percent. In the short term, high energy prices and a weak euro may dampen energy demand growth in Europe (particularly given the region's high tax burden on energy sources). In the long run, however, energy consumption in Western Europe is expected to increase by 1.0 percent per year in *IEO2001*, largely unchanged from the projection in last year's reference case forecast.

Japan's economy showed modest improvement in 2000. After a 2.5-percent decline in GDP in 1998 and virtually no economic growth in 1999, the country's GDP grew by an estimated 1.9 percent in 2000 [***22***]. Japan's government ended its zero-interest rate policy in August 2000, and domestic banks raised their prime lending rates by one-eighth of a percentage point, but the strength of the yen did not seem to be affected. There is some fear, however, that high world oil prices may slow the recovering economy. Increases in consumer spending cannot be described as "sustained," and the Japanese government is considering a 10 trillion yen stimulus package to boost economic growth. The government implemented a 22 trillion yen economic stimulus package in November 1998 [***23***].

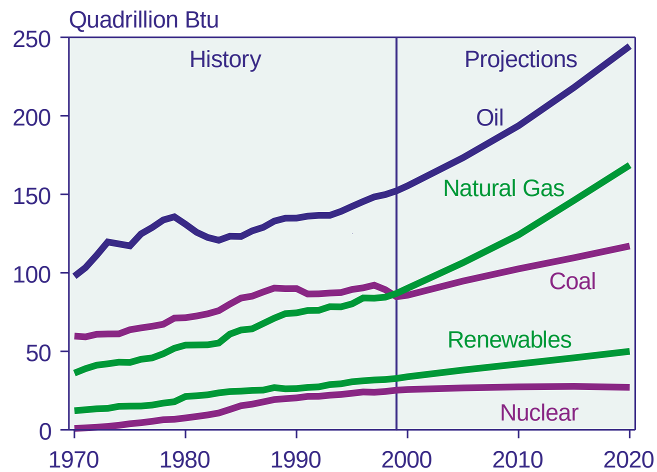
Outlook for Primary Energy Consumption

The *IEO2001* reference case projects that consumption of every primary energy source will increase over the 21-year forecast horizon, with the exception of nuclear power (Figure 17). Most of the increment in energy consumption in the reference case is in the form of fossil fuels (oil, natural gas, and coal), because *IEO2001* projects that fossil fuel prices will remain relatively low through the forecast period, and that the cost of generating energy from non-fossil energy will not be as competitive. However, should environmental programs or government policies designed to limit or reduce greenhouse gas emissions, such as the Kyoto Protocol[2] or its successor, come into play, 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 *IEO2001* projections only account for government policies or programs in place as of October 1, 2000.

Oil is expected to remain the dominant energy fuel throughout the forecast period, as it has been 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 with oil products. The *IEO2001* reference case forecast assumes that oil use for electricity generation will decline, as other fuels (mostly natural gas) will be more favorable alternatives to oil-fired generation.

In the developing world, oil consumption is projected to increase for all end uses. In countries where noncommercial fuels have been widely used in the past (such as fuel wood for cooking and home heating), diesel generators are now sometimes being used to dissuade populations from decimating surrounding forests and vegetation. Because the natural gas infrastructure necessary to expand gas use has not been as widely established in the developing world as it has in the industrialized world, gas use is expected to grow in the

Figure 17. 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, January 2001). **Projections:** EIA, World Energy Projection System (2001).

[2]The Kyoto Climate Change Protocol, devised by the United Nations Framework Convention on Climate Change, requires reductions or limits to the growth of carbon emissions within the Annex I countries (Australia, Austria, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Lithuania, Luxembourg, the Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, the United Kingdom, and the United States) between 2008 and 2012, resulting in a 4-percent reduction in emissions relative to 1990 levels. The Protocol has not yet been ratified by any of the Annex I countries.

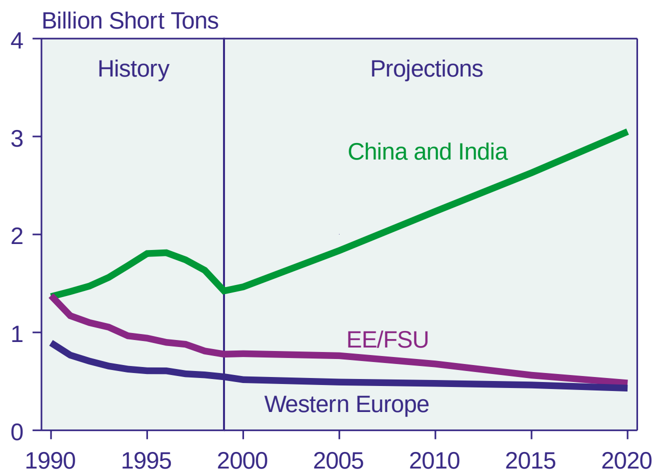
developing world, but not enough to accommodate all of the increase in demand for energy.

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 as high as the rate for coal. Natural gas consumption is projected to rise from 84 trillion cubic feet in 1999 to 162 trillion cubic feet in 2020, primarily for electricity generation. Gas is increasingly seen as the desired alternative for electric power, given the efficiency of combined-cycle gas turbines relative to coal- or oil-fired generation, and because 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 1.7 billion short tons (36 percent) 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 replace coal, to fuel new growth in electric power generation, and for other industrial and building sector uses (Figure 18). 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 more than 90 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 2,636 billion kilowatthours in 2015 before declining to 2,582 billion kilowatthours at the end of the forecast period. Most of the growth in nuclear capacity in the reference case is expected to occur in the developing world (particularly in developing Asia), where consumption of electricity generated from nuclear plants is projected to increase by 4.9 percent per year between 1999 and 2020. In contrast, older reactors are expected to be retired in the industrialized world and the FSU, and few new reactors are planned to replace them. Exceptions include France and Japan, where several new reactors are expected to begin operating in the next decade or so. On the other hand, if the Kyoto Protocol or a successor agreement were enacted, it is possible that the lives of non-carbon-emitting nuclear facilities could be extended and the decline of nuclear generation forestalled if industrialized countries attempt to reduce their greenhouse gas emissions.

Figure 18. World Coal Consumption by Region, 1990-2020



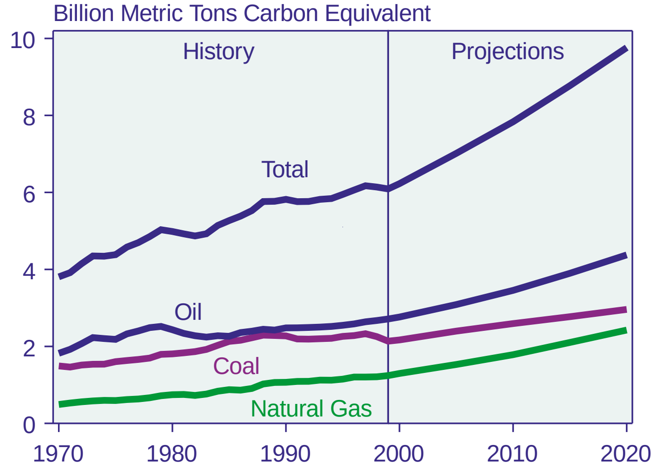
Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, World Energy Projection System (2001).

Consumption of electricity from hydropower and other renewable energy sources is projected to grow by 2.0 percent annually in the *IEO2001* 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. Like nuclear power, renewable energy could get a boost if the Annex I countries (those countries that have the responsibility to reduce or limit greenhouse gas emissions under the Kyoto Protocol) enacted policies requiring reductions in greenhouse gas emissions. Such policies would encourage nations to use non-carbon-emitting energy sources to reduce their reliance on fossil fuels and, consequently, reduce their emissions.

Outlook for Carbon Dioxide Emissions

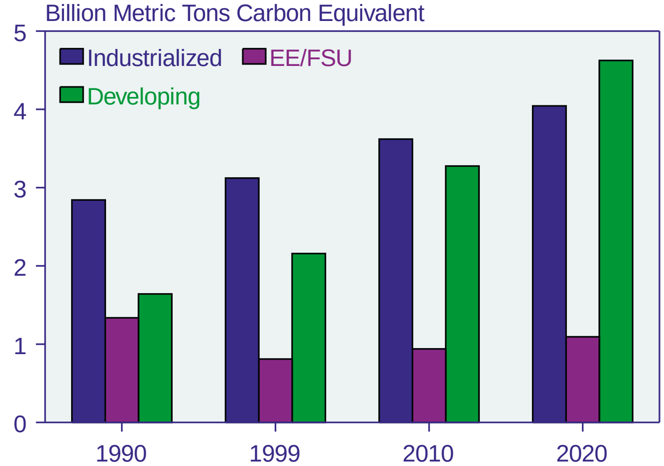
If fossil fuel consumption grows to the levels projected in the *IEO2001* reference case, carbon dioxide emissions are expected to rise to 7.8 billion metric tons carbon equivalent in 2010 and to 9.8 billion metric tons by 2020 (Figure 19). Much of the increase is expected in the developing countries, 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 3.7 percent per year between 1999 and 2020. Developing countries alone account for 81 percent of the projected increment in world carbon emissions between 1990 and 2010 and 76 percent between 1990 and 2020 (Figure 20). Continued heavy reliance on coal and other fossil fuels projected for the developing countries ensures that even if the Annex I countries were to adopt the terms of the Kyoto Protocol, worldwide emissions would still grow substantially over the forecast horizon.

Figure 19. World 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, January 2001). **Projections:** EIA, World Energy Projection System (2001).

Figure 20. World 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, January 2001). **Projections:** EIA, World Energy Projection System (2001).

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 use 0.7 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.

The Kyoto Protocol, if ratified and implemented, could influence future patterns of energy consumption, as well as carbon dioxide emissions. As of February 2001, 83 countries and the European Community had signed the treaty. It was ratified by 32 signatories but not by any of the Annex I countries that would be required to limit or reduce their greenhouse gas emissions relative to 1990 levels under the terms of the Protocol [***24***]. The Protocol will not enter into force until the "ninetieth day after the date on which not less than 55 Parties to the Convention, incorporating Annex I Parties which accounted in total for at least 55 percent of the total carbon dioxide emissions for 1990 from that group, have deposited their instruments of ratification, acceptance, approval or accession."

If the Kyoto Protocol became law 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).[3] 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 *IEO2001* reference case projections have not been adjusted to account for the impact of any potential policy. Carbon dioxide emissions in the industrialized Annex I countries alone are projected to grow to 3,475 million metric tons carbon equivalent in 2010 and 3,841 million metric tons in 2020, from 2,758 million metric tons in 1990 (Figure 21). About half 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 4,276 million metric tons carbon equivalent in 2010 and 4,771 million metric tons in 2020 from 3,890 million metric tons in 1990.

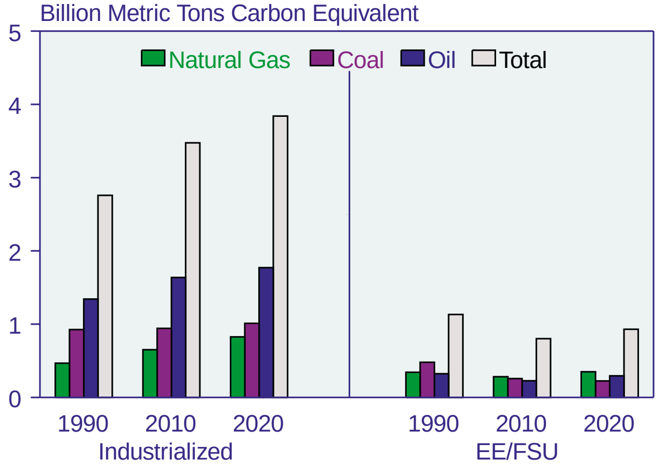
Oil accounts for more than 40 percent of the projected increase in carbon dioxide emissions in the industrial Annex I countries, which rely heavily on oil for transportation and, at present, have few economical alternatives. Only 8 percent of the projected increase in carbon

[3]This range was calculated by removing consumption of the most carbon-intensive fossil fuel possible, coal, and the least carbon-intensive 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.

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 431 million metric tons in the Annex I transitional economies of the EE/FSU between 1990 and 1999, from 1,132 million metric tons to 700 million metric tons carbon equivalent. Emissions in the Annex I EE/FSU countries are expected to rise to 802 million metric tons carbon equivalent in 2010 and to 930 million metric tons in 2020, remaining below their 1990 level even at the end of the forecast horizon.

Figure 21. Carbon Dioxide Emissions in the Annex I Countries by Fuel Type, 1990, 2010, and 2020



Sources: **1990:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **2010 and 2020:** EIA, World Energy Projection System (2001).

IEO2000 projected that the Annex I EE/FSU countries would provide 318 million metric tons of potential emissions allowances for the Annex I emissions reduction effort in 2010. In *IEO2001* the projection is slightly higher, at 348 million metric tons. Without allowance trading, the industrialized Annex I countries would have to reduce their emissions by a combined 901 million metric tons (or 26 percent) relative to the reference case projection for 2010 (Table 2). Because the EE/FSU Annex I countries are projected to emit about 348 million metric tons less than their Protocol targets, however, Annex I member countries as a whole need to reduce their combined emissions by only 554 million metric tons (or 13 percent) in 2010 relative to the baseline projection.

Alternative Growth Cases

A major source of uncertainty in the *IEO2001* forecast is the expected rate of future economic growth. As a measure of economic growth *IEO2001* uses gross domestic product (GDP), which is accompanied by its own issues of uncertainty (see box on page 15). *IEO2001* includes a high economic growth case and a low economic growth

Table 2. Carbon Dioxide Emissions in the Annex I countries, 1990 and 2010, and Effects of the Kyoto Protocol in 2010
(Million Metric Tons Carbon Equivalent)

Region and Country	1990 Emissions	2010 Baseline Projection: *IEO2001* Reference Case	2010 Baseline Projection: Percent Change from 1990	2010 Kyoto Protocol Target	Reduction From 2010 Baseline	Percent Change: From 1990	Percent Change: From 2010 Baseline
Annex I Industrialized Countries							
North America	1,472	1,979	34	1,370	604	-7	-31
United States	1,345	1,809	34	1,251	558	-7	-31
Canada	126	165	31	119	46	-6	-28
Western Europe	930	1,040	12	856	184	-8	-18
Industrialized Asia	357	461	29	347	113	-3	-25
Japan	269	330	23	253	77	-6	-23
Australasia	88	130	48	94	36	7	-28
Total	**2,758**	**3,475**	**26**	**2,573**	**901**	**-7**	**-26**
Annex I Transitional Economies							
Former Soviet Union	853	593	-30	851	-258	-0	44
Eastern Europe	279	209	-25	298	-89	7	43
Total	**1,132**	**802**	**-29**	**1,149**	**-348**	**2**	**43**
Total Annex I Countries	**3,890**	**4,276**	**10**	**3,723**	**554**	**-4**	**-13**

Sources: **1990:** Energy Information Administration (EIA), *Emissions of Greenhouse Gases in the United States 1999*, DOE/EIA-0573(99) (Washington, DC, October 2000); and EIA, *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **2010:** EIA, World Energy Projection System (2001).

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 ideas about possible economic growth paths.

For the high and low economic growth cases, different assumptions are made about the range of possible economic growth rates among the industrial, transitional EE/FSU, and developing economies. For the industrialized countries, one percentage point is added to the reference case GDP growth rates for the high economic growth case and one percentage point is subtracted from

Uncertainty in Measures of Gross Domestic Product

The GDP forecasts underlying the *IEO2001* energy forecasts are themselves subject to uncertainty from two sources. First, because the GDP forecasts are projections of trend growth, abstracting from cyclical movements and unexpected shocks to the economy, there is the possibility that the perceived trends may not actually achieve expected levels. This type of uncertainty is inherent in all forecasts, and forecasters try to minimize it by looking at past experience. Clearly, the longer the period of the forecast the greater the uncertainty, because the more likely it is that events will not go as expected.

The second source of uncertainty about GDP forecasts has to do with the variation in the methods and accuracy with which GDP is measured among countries and over time. This source of uncertainty is the result of methodological and measurement issues and would be minimized if a common methodology and data collection method were used across countries and over time to estimate GDP.

The GDP forecasts for *IEO2001* depend on the national statistical agencies' definition of what is included in the measurement of output. *IEO2001* uses real (inflation-adjusted) GDP, which ultimately relies on the statistics released by each national statistical agency. Comparing across countries, even though conceptually GDP has common meaning, it may not be measured consistently across nations. There are several examples illustrating differences in treatment both within the more industrialized nations and among the developing countries.

Over the past year, the United States has released revised historical GDP numbers, incorporating changes in estimation of inflation, reclassification of certain investment expenditures, and more complete data. As a result, the historical GDP growth rate from 1959 to 1998 has been revised upward by 0.2 percent per year. The Bureau of Economic Analysis (BEA), the statistical agency responsible for estimating U.S. GDP, uses a methodology to estimate inflation that is not commonly used in the other industrialized countries. If a common methodology were adopted, the economic growth forecasts for some countries would be different from those published in the past.

Measurement of price changes is a central source of differences in the calculation of real output growth. The United States changed to a chain-weighted approach in 1992, rather than fixed-year prices, in order to remove substitution bias and reduce the impact of changing the base year much less noticeable in understanding economic growth.[a] Most of the other industrialized nations have not calculated price changes using chain-weighted indices but continue to use fixed-year prices to calculate real output.

Some nations, such as China and other centrally planned economies, use a "comparable prices" approach that applies constant "administrative prices" to value nominal output, rather than calculating a deflator-based estimate of price change. Data from state enterprises determine the administrative prices. Typically, state enterprise price data are applied to a wide variety of similar goods without adjusting for variation in product characteristics. Relying on administrative prices to value real output leads to greater uncertainty in estimates of inflation and, consequently, real output growth.

In developing countries, some economic activities are not recorded or monetized. National statistical agencies have devised various methods to estimate their contribution to GDP. As methodologies improve and/or more complete information becomes available over time, their GDP estimates probably will be revised. At present, however, it is difficult to predict for each economy how the changes will be made—a consideration that adds to the uncertainty about their expected GDP growth.

Finally, many countries are moving toward United Nations System of National Accounts for reporting their statistics, which is a step toward reporting country growth in a consistent framework. When all countries can convert their detailed national statistics into this framework, the "measurement uncertainty" in GDP estimates will be significantly reduced.

[a]For a description of chain-weighted indexes, see J.S. Landefeld and R. Parker, "BEA's Chain Indexes, Time Series and Measures of Long-Term Economic Growth" *Survey of Current Business* (May 1997).

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 *IEO2001* reference case shows total world energy consumption reaching 607 quadrillion Btu in 2020, with the industrialized world projected to consume 270 quadrillion Btu, the transitional EE/FSU countries 72 quadrillion Btu, and the developing world 264 quadrillion Btu (Figure 22). In the high economic growth case, total world energy use in 2020 is projected to be 713 quadrillion Btu, 106 quadrillion Btu higher than in the reference case. Under the assumptions of the low economic growth case, worldwide energy consumption in 2020 would be 94 quadrillion Btu lower than in the reference case (or 513 quadrillion Btu). Thus, there is a substantial range of 200 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 8,204 million metric tons carbon equivalent in the low economic growth case (1,558 million metric tons less than the reference case projection) and 11,505 million metric tons carbon equivalent in the high economic growth case (1,743 million metric tons higher than the reference case projection).

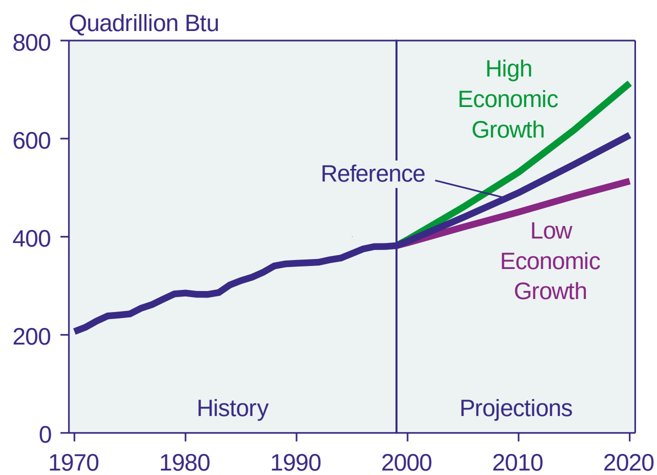
Trends in Energy Intensity

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. The EE/FSU economies have always 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 begin 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 23).

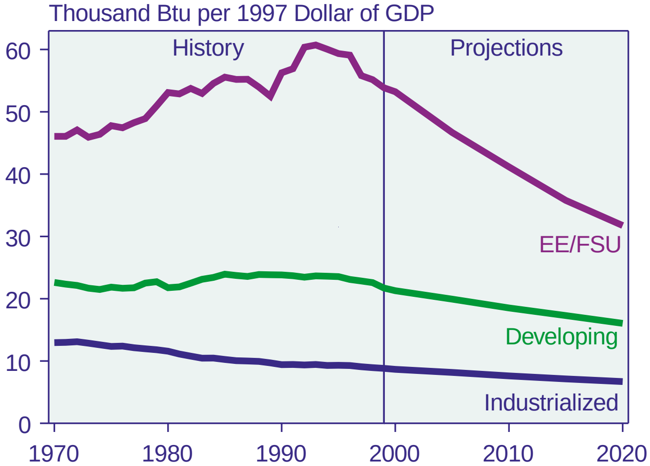
The stage of economic development and the standard of living of individuals in a given region strongly influence the link between economic growth and energy demand. Advanced economies with high living standards have relatively high energy use per capita, but they also tend to be economies where per capita energy use is stable or changes occur very slowly, and increases in energy use tend to correlate with employment and population growth.

Figure 22. Total World Energy Consumption in Three Cases, 1970-2020



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

Figure 23. 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, January 2001). **Projections:** EIA, World Energy Projection System (2001).

In the industrialized countries, there is a high penetration rate of modern appliances and motorized personal transportation equipment. As a result, increases in personal income tend to result in spending on goods and services that are not energy intensive. 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.

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 the developing countries are assumed to decline on average by 61 percent (which was the single greatest annual improvement observed between 1990 and 1999), energy consumption in the developing world would be just 138 quadrillion Btu in 2020, about 126 quadrillion Btu less than the reference case estimate of 264 quadrillion Btu. On the other hand, if energy intensities in the developing world are assumed to increase by 134 percent (the highest annual rate of growth observed in the 9-year period), energy consumption in the developing world would climb to 836 quadrillion Btu in 2020—more than three times the reference case projection.

Forecast Comparisons

Another way to examine the uncertainty associated with the *IEO2001* projections is to compare them with those derived by other forecasters. Four organizations provide forecasts comparable to those in *IEO2001*. The International Energy Agency (IEA) provides "business as usual" projections out to the year 2020 in its *World Energy Outlook 2000*. Standard & Poor's Platt's (S&P) also provides energy forecasts by fuel to 2020 in its *World Energy Service: World Outlook 1999*. Petroleum Economics, Ltd. (PEL) and Petroleum Industry Research Associates (PIRA) publish world energy forecasts, but only to the years 2015 and 2010, respectively. For this comparison, 1997 is used as the base year for all the forecasts.

Regional breakouts among the forecasting groups vary, complicating the comparisons. For example, *IEO2001* 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 *IEO2001* projections and added to Central and South America to form "Latin America" country grouping that matches the other series. S&P and PIRA include only Japan in industrialized Asia, whereas industrialized Asia in the *IEO2001* forecast comprises Japan, Australia, New Zealand, and the U.S. Territories. S&P and *IEO2001* include Turkey in 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 *IEO2001*. 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 3). The growth rates for energy consumption among the reference case forecasts for the 1997-2010 time period are relatively similar, ranging between 2.0 and 2.3 percent per year. All the forecasts for total energy consumption fall well within the range of variation defined by the *IEO2001* low and high economic growth cases and, in fact, are all within a range of 0.3 percentage points.

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 0.8 percentage points among the forecasts. *IEO2001* projects the lowest growth in energy demand in the region at 3.3 percent per year between 1997 and 2010. PIRA and PEL project the highest average growth for the 1997-2010 period, at 4.1 percent per year.

Among the nations of developing Asia, the widest variations in the energy consumption forecasts are seen for China. Both PIRA and PEL project growth rates of 4.3 percent per year, higher than projected in the *IEO2001* high economic growth case (4.0 percent per year).

Table 3. Comparison of Energy Consumption Growth Rates by Region, 1997-2010
(Average Annual Percent Growth)

Region	IEO2001 Low Growth	IEO2001 Reference	IEO2001 High Growth	IEO2000	S&P	IEA	PIRA	PEL
Industrialized Countries	**0.9**	**1.3**	**1.6**	**1.2**	**1.4**	**1.2**	**0.9**	**1.1**
United States and Canada	1.2	1.5	1.8	1.3	1.4	1.1	1.3	1.2
Western Europe	0.7	1.1	1.5	1.0	1.5	1.3	0.9	1.1
Asia	0.3	0.8	1.3	1.1	1.0[a]	1.1	0.9[a]	0.6
EE/FSU	**0.6**	**1.1**	**2.2**	**1.3**	**1.2**	**1.4**	**1.8**	**0.9**
Developing Countries	**2.1**	**3.2**	**4.1**	**3.7**	**3.7**	**3.6**	**4.1**	**3.8**
Asia	2.0	3.3	4.1	4.1	3.7	3.9	4.1	4.1
China	1.5	3.2	4.0	4.9	3.6	3.6	4.3	4.3
Other Asia[b]	2.5	3.3	4.2	3.2	3.8	4.2	3.9	3.8
Middle East	2.1	3.0	3.9	3.0	3.4	2.7	3.2	3.4
Africa	1.7	2.6	3.4	2.5	2.6	2.9	3.3	2.7
Latin America	2.7	3.6	4.5	3.7	4.4	3.3	3.0	3.5
Total World	**1.3**	**2.0**	**2.6**	**2.1**	**2.3**	**2.1**	**2.2**	**2.1**

[a]Japan only.
[b]Other Asia includes India and South Korea.
Sources: ***IEO2001*:** Energy Information Administration (EIA), World Energy Projection System (2001). ***IEO2000*:** EIA, *International Energy Outlook 2000*, DOE/EIA-0484(2000) (Washington, DC, March 2000), Table A1, p. 169. **S&P:** Standard & Poor's Platt's, *World Energy Service: World Outlook 1999* (Lexington, MA, January 1999), p. 3. **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 2000), Tables II-4, II-6, and II-7. **PEL:** Petroleum Economics, Ltd., *Oil and Energy Outlook to 2015* (London, United Kingdom, February 2000).

IEO2000 projected a reference case growth rate of 4.9 percent per year between 1997 and 2010, 1.5 percentage points higher than the *IEO2001* reference case projection of 3.2 percent per year.

The lower projection for China's energy consumption in this year's forecast reflects a precipitous drop in energy use in China between 1997 and 1999, the historical year on which the *IEO2001* 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 *IEO2001* 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 an 8-percent increase in energy use over the 2-year period).

Projections for the EE/FSU differ by a range of 0.9 percentage points, varying from 0.9 percent annual growth in energy demand between 1997 and 2010 (PEL) to 1.8 percent per year (PIRA). *IEO2001* projects that energy use in the EE/FSU will increase by 1.1 percent per year over the period. Although there clearly is a great deal of uncertainty among the forecasts about how fast the economic recovery might progress over the next decade, all the energy consumption growth forecasts fall within the range defined by the *IEO2001* high and low economic growth cases.

Latin America is another region for which large difference among the forecasts are evident. The projected growth rates for energy demand from 1997 to 2010 range from 3.0 percent per year (PIRA) to 4.4 percent (S&P). The *IEO2001* reference case projects a growth rate of 3.6 percent per year for Latin America. The S&P forecast, published in January 1999, is the oldest one in this comparison, released before the economic recession that hit the region in 1999, and also the most optimistic. If S&P is not considered, the projected growth rates are separated by only 0.6 percentage points per year.

Only *IEO2001* and PEL provide forecasts for energy use in 2015, the end of the PEL forecast horizon (Table 4), and their projections for worldwide growth in energy consumption between 1997 and 2015 are similar. *IEO2001* projects average growth of 2.1 percent per year and PEL 2.0 percent per year. Regionally, however, *IEO2001* expects a much faster pace of recovery for the EE/FSU over the 1997-2015 period (1.4 percent per year) than does PEL (0.9 percent per year). *IEO2001* 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.

Table 4. Comparison of Energy Consumption Growth Rates by Region, 1997-2015
(Average Annual Percent Growth)

Region	*IEO2001*			*IEO2000*	PEL
	Low Growth	Reference	High Growth		
Industrialized Countries	**0.9**	**1.2**	**1.5**	**1.1**	**0.5**
United States and Canada	1.1	1.4	1.7	1.2	1.0
Western Europe	0.6	1.0	1.4	0.9	0.9
Asia	0.4	0.9	1.5	0.9	0.4
EE/FSU	**0.9**	**1.4**	**2.5**	**1.3**	**0.9**
Former Soviet Union	1.0	1.5	2.7	1.2	0.7
Eastern Europe	0.4	1.2	1.8	1.6	1.4
Developing Countries	**2.2**	**3.4**	**4.3**	**3.4**	**3.6**
Asia	2.1	3.4	4.3	3.7	3.8
China	1.7	3.6	4.5	4.4	3.9
Other Asia[a]	1.5	3.1	3.2	3.0	3.8
Middle East	2.2	3.1	4.0	2.8	3.1
Africa	1.7	2.6	3.6	2.5	2.5
Latin America	2.6	3.2	4.7	3.6	3.5
Total World	**1.3**	**2.1**	**2.7**	**2.0**	**2.0**

[a]Other Asia includes India and South Korea.

Sources: ***IEO2001*:** Energy Information Administration (EIA), World Energy Projection System (2001). ***IEO2000*:** EIA, *International Energy Outlook 2000*, DOE/EIA-0484(2000) (Washington, DC, March 2000), Table A1, p. 169. **PEL:** Petroleum Economics, Ltd., *Oil and Energy Outlook to 2015* (London, United Kingdom, February 2000).

IEO2001 is much more optimistic about the prospects for growth in energy use in the FSU, projecting an average increase of 1.5 percent per year, than is PEL (0.7 percent per year).

IEO2001 is also much more optimistic than is PEL about growth in the industrialized world's energy consumption (1.2 percent per year vs. 0.5 percent per year between 1997 and 2015). The *IEO2001* projections are higher than PEL's for each of the three regions of the industrialized world. Higher expectations for developing Asia in the PEL forecast, however, offset the more pessimistic forecasts for the FSU and industrialized nations.

IEO2001, IEA, and S&P provide energy consumption projections for 2020. Table 5 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 2.3 percent per year (S&P), with *IEO2001* at 2.1 percent per year. There are also relatively large differences among the forecasts for the EE/FSU, with growth rate projections ranging from 1.3 percent per year (S&P) to 1.6 percent per year (IEA), with *IEO2001* at 1.4 percent per year.

There are larger differences among the three forecasts for energy demand growth in the industrialized region from 1997 to 2020. IEA is much less optimistic about growth in the United States and Canada (0.9 percent per year) than is S&P (1.1 percent per year) or *IEO2001* (1.3 percent per year). S&P is more optimistic about growth in industrial Asia (1.5 percent per year) than is *IEO2001* (1.1 percent per year) or IEA (1.0 percent per year).

For some regions of the developing world, the three forecasts are similar. The projections for Africa's energy consumption growth range between 2.6 percent per year (*IEO2001* and S&P) and 2.8 percent per year (IEA). In addition, all three expect a combined developing Asia (including China) to grow by about the same rate over the time horizon (3.4 percent per year in *IEO2001*, 3.6 percent per year in the S&P forecast, and 3.7 percent per year in the IEA forecast). Within developing Asia, however, there are strong differences among the forecasts for China. IEA and S&P project that energy use in China will grow more slowly over the 1997-2020 period than in "other Asia," but *IEO2001* expects the opposite.

A key reason for the differences among the various forecasts is that they are based on different expectations about future economic growth rates. *IEO2001*, PIRA, and PEL provide GDP growth rate projections for the 1997-2010 period (Table 6), and all have similar expectations for economic growth in the industrialized world, projecting higher growth for the United States, Canada, and Western Europe than for industrialized Asia. The *IEO2001* and PIRA forecasts for GDP growth in the United States and Canada are higher than the S&P and PEL forecasts. The GDP assumptions in *IEO2001* for the United States and Canada are a full percentage point higher than those in *IEO2000*.

Table 5. Comparison of Energy Consumption Growth Rates by Region, 1997-2020
(Average Annual Percent Growth)

Region	*IEO2001* Low Growth	*IEO2001* Reference	*IEO2001* High Growth	*IEO2000*	S&P	IEA
Industrialized Countries	**0.8**	**1.2**	**1.5**	**1.0**	**1.2**	**0.9**
United States and Canada	1.0	1.3	1.6	1.1	1.1	0.9
Western Europe	0.6	1.0	1.3	0.9	1.2	1.0
Asia	0.6	1.1	1.6	0.9	1.5	1.0
EE/FSU	**0.9**	**1.4**	**2.5**	**1.5**	**1.3**	**1.6**
Developing Countries	**2.2**	**3.4**	**4.3**	**3.5**	**3.5**	**3.4**
Asia	2.1	3.4	4.3	3.7	3.6	3.7
China	1.8	3.7	4.6	4.3	3.3	3.4
Other Asia[a]	2.3	3.2	4.1	3.0	3.8	4.0
Middle East	2.2	3.1	4.1	2.9	3.3	2.8
Africa	1.6	2.6	3.5	2.6	2.6	2.8
Latin America	2.2	3.8	4.9	3.7	4.2	3.1
Total World	**1.3**	**2.1**	**2.8**	**2.1**	**2.3**	**2.0**

[a]Other Asia includes India and South Korea.

Sources: ***IEO2001*****:** Energy Information Administration (EIA), World Energy Projection System (2001). ***IEO2000*****:** EIA, *International Energy Outlook 2000*, DOE/EIA-0484(2000) (Washington, DC, March 2000), Table A1, p. 169. **S&P:** Standard & Poor's Platt's, *World Energy Service: World Outlook 1999* (Lexington, MA, January 1999), p. 3. **IEA:** International Energy Agency, *World Energy Outlook 2000* (Paris, France, November 2000), pp. 364-418.

Table 6. Comparison of Economic Growth Rates by Region, 1997-2010
(Average Annual Percent Growth in Gross Domestic Product)

Region	*IEO2001* Low Growth	*IEO2001* Reference	*IEO2001* High Growth	*IEO2000*	S&P	PIRA	PEL[a]
Industrialized Countries	**2.0**	**2.7**	**3.6**	**2.2**	**2.2**	**2.8**	**—**
United States and Canada	3.3	3.5	4.4	2.5	2.6	3.4	2.8
Western Europe	1.8	2.5	3.4	2.4	2.4	2.5	2.5
Asia	-0.6	1.2	2.0	1.2	1.1	1.5	1.2
EE/FSU	**0.8**	**3.5**	**6.1**	**3.4**	**3.5**	**3.9**	**—**
Former Soviet Union	-0.2	3.1	5.5	2.9	2.2	—	1.8
Eastern Europe	2.3	4.3	7.0	4.2	4.5	—	3.4
Developing Countries	**2.4**	**4.9**	**6.1**	**4.8**	**4.5**	**4.8**	**—**
Asia	2.9	5.7	6.9	5.2	5.1	5.3	5.3
China	5.1	7.4	8.9	6.9	6.8	6.1	6.7
Other Asia[b]	1.6	4.8	5.8	4.4	4.2	4.4	—
Middle East	1.5	3.8	5.1	3.3	3.3	3.9	3.0
Africa	2.2	4.0	5.4	3.1	3.1	3.8	3.4
Latin America	2.0	4.0	5.3	4.2	4.1	3.5	3.1
Total World	**2.1**	**3.2**	**4.2**	**2.7**	**2.8**	**3.8**	**2.9**

[a]North America includes only the United States. Industrialized Asia includes only Japan.
[b]Other Asia includes India and South Korea.

Sources: ***IEO2001*****:** Energy Information Administration (EIA), World Energy Projection System (2001). ***IEO2000*****:** EIA, *International Energy Outlook 2000*, DOE/EIA-0484(2000) (Washington, DC, March 2000), Table A1, p. 169. **S&P:** Standard & Poor's Platt's, *World Energy Service: World Outlook 1999* (Lexington, MA, January 1999). **PIRA:** PIRA Energy Group, *Retainer Client Seminar* (New York, NY, October 2000), Table II-1. **PEL:** Petroleum Economics, Ltd., *Oil and Energy Outlook to 2015* (London, United Kingdom, February 2000).

Expectations for economic growth in the EE/FSU region as a whole from 1997 to 2010 are also similar across the forecasts, ranging from 3.5 percent per year (S&P) to 3.9 percent per year (PIRA). PEL, which does not provide GDP growth rate assumptions for the total EE/FSU region, is less optimistic about the potential for growth both in Eastern Europe and in the FSU than is *IEO2001*, and presumably also for the entire region. Among the forecasts that provide separate projections for Eastern Europe and the FSU, there is general consensus that economic growth in the FSU will be slower than in Eastern Europe.

The *IEO2001* forecast is the most optimistic about economic growth in developing Asia between 1997 and 2010. The growth rate projections for developing Asia range from 5.1 percent per year (S&P) to 5.7 percent per year (*IEO2001*). In all the forecasts, the highest GDP growth rate is expected for China, ranging from 6.1 percent per year (PIRA) to 7.4 percent per year (*IEO2001*), and all the projections fall within the range defined by the *IEO2001* high and low economic growth cases. PEL tends to be the least optimistic in terms of economic growth for the developing regions outside of China, providing the lowest expected growth rates for the Middle East and Latin America. And, were it not for the somewhat lower estimate from S&P for Africa's average annual economic growth between 1997 and 2010, PEL's growth rate projections would also be the lowest for that region.

Three forecasts—*IEO2001*, S&P, and IEA—provide GDP growth rate projections for the 1997-2020 period (Table 7). Again, *IEO2001* is more optimistic about economic growth in the United States and Canada than are the two other forecasts. IEA projects lower economic growth rates for North America and Western Europe but higher growth for industrialized Asia, and S&P projects higher growth for Western Europe and industrialized Asia than does *IEO2001*.

IEA projects a slightly slower rate of economic recovery in the EE/FSU countries than does *IEO2001*. The difference may be explained by IEA's inclusion of the Czech Republic, Hungary, and Poland—three of Eastern Europe's strongest economies—in Western Europe (OECD Europe) rather than the EE/FSU.

Finally, the projections vary not only with respect to levels of total energy demand and economic growth but also with respect to the composition of primary energy inputs. Four of the forecasts—*IEO2001*, IEA, PIRA, and S&P—provide energy consumption projections by fuel in 2010 (Table 8). S&P does not provide a breakout of nuclear and other sources of electricity generation but instead provides a single forecast for "primary electricity."

Table 7. Comparison of Economic Growth Rates by Region, 1997-2020
(Average Annual Percent Growth in Gross Domestic Product)

Region	*IEO2001* Low Growth	*IEO2001* Reference	*IEO2001* High Growth	*IEO2000*	S&P	IEA
Industrialized Countries	**1.8**	**2.5**	**3.4**	**2.5**	**2.3**	**—**
United States and Canada	2.7	3.1	4.1	2.7	2.4	2.1
Western Europe	1.6	2.3	3.3	2.6	2.4	2.1
Asia	0.0	1.5	2.3	1.8	1.9	1.7
EE/FSU	**1.8**	**4.0**	**6.7**	**4.0**	**3.5**	**3.1**
Former Soviet Union	1.3	3.8	6.5	3.5	3.1	—
Eastern Europe	2.6	4.2	7.1	4.9	4.1	—
Developing Countries	**2.9**	**5.0**	**6.3**	**5.5**	**4.8**	**—**
Asia	3.3	5.7	7.0	6.1	5.3	—
China	4.6	7.0	8.5	7.6	6.7	5.2
Other Asia[b]	2.6	4.9	6.1	5.3	4.6	4.2-4.9
Middle East	2.2	4.3	5.7	4.1	4.1	3.2
Africa	2.3	3.9	5.3	3.5	3.6	2.9
Latin America	2.5	4.2	5.5	4.6	4.3	3.2
Total World	**2.0**	**3.2**	**4.3**	**3.1**	**2.9**	**3.1**

[a]North America includes only the United States. Industrialized Asia includes only Japan.
[b]Other Asia includes India and South Korea.

Sources: ***IEO2001*:** Energy Information Administration (EIA), World Energy Projection System (2001). ***IEO2000*:** EIA, *International Energy Outlook 2000*, DOE/EIA-0484(2000) (Washington, DC, March 2000), Table A1, p. 169. **S&P:** Standard & Poor's Platt's, *World Energy Service: World Outlook 1999* (Lexington, MA, January 1999). **IEA:** International Energy Agency, *World Energy Outlook 2000* (Paris, France, November 2000), p. 352.

In terms of oil consumption, all the forecasts expect similar growth worldwide between 1997 and 2010. Oil demand is projected to increase by between 1.9 percent per year (PIRA) and 2.1 percent per year (S&P and *IEO2001*). All the forecasts expect natural gas use to grow more rapidly than other fuels between 1997 and 2010. *IEO2001* expects slower growth in coal use over the 13-year period than do the other forecasts. The *IEO2001* projection is for 0.8-percent average annual growth, as compared with a range of 1.7 percent per year (IEA) to 2.2 percent per year (PIRA) in the other forecasts.

IEO2001 is more optimistic about the prospects for nuclear electricity generation, projecting average growth of 1.0 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) 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, and that generation from nuclear power will not decline as rapidly or by as much as projected in *IEO2000*.

PEL and *IEO2001* provide world energy consumption projections by fuel for 2015 (Table 9). The two forecasts reflect similar views about oil and renewable energy consumption between 1997 and 2015 but different views about natural gas, coal, and nuclear power. *IEO2001* 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 *IEO2001*. *IEO2001* projects much higher growth in nuclear power use (0.8 percent per year) than does PEL (0.2 percent per year).

IEO2001, IEA, and S&P are the only forecasts that provide projections for 2020 (Table 10). The three forecasts

Table 8. Comparison of World Energy Consumption Growth Rates by Fuel, 1997-2010
(Average Annual Percent Growth)

Fuel	*IEO2001*			*IEO2000*	S&P	IEA	PIRA	PEL
	Low Growth	Reference	High Growth					
Oil	1.4	2.1	2.7	1.9	2.1	2.0	1.9	2.0
Natural Gas	2.1	3.1	3.8	3.3	3.2	2.8	3.4	3.0
Coal	0.4	0.8	1.5	1.7	2.1	1.7	2.2	1.8
Nuclear	0.8	1.0	1.5	0.6	—[a]	0.8	0.7	0.6
Renewable/Other	1.5	2.2	2.8	2.2	—[a]	2.5	1.8	1.9
Total	**1.3**	**2.0**	**2.6**	**2.1**	**2.3**	**2.1**	**2.2**	**2.1**
Primary Electricity	1.2	1.7	2.2	1.5	1.7	1.5	1.3	1.4

[a]S&P reports nuclear and hydroelectric power together as "primary electricity."

Sources: ***IEO2001*:** Energy Information Administration (EIA), World Energy Projection System (2001). ***IEO2000*:** EIA, *International Energy Outlook 2000*, DOE/EIA-0484(2000) (Washington, DC, March 2000), Table A1, p. 169. **S&P:** Standard & Poor's Platt's, *World Energy Service: World Outlook 1999* (Lexington, MA, January 1999), p. 3. **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 1999), Table II-8. **PEL:** Petroleum Economics, Ltd., *Oil and Energy Outlook to 2015* (London, United Kingdom, February 2000).

Table 9. Comparison of World Energy Consumption Growth Rates by Fuel, 1997-2015
(Average Annual Percent Growth)

Fuel	*IEO2001*			*IEO2000*	PEL
	Low Growth	Reference	High Growth		
Oil	1.4	2.2	2.9	2.0	2.0
Natural Gas	2.3	3.1	3.9	3.1	2.8
Coal	0.4	1.0	1.7	1.5	1.6
Nuclear	0.5	0.8	1.3	0.1	0.2
Renewable/Other	1.4	2.1	2.7	1.9	1.9
Total	**1.3**	**2.1**	**2.7**	**2.0**	**2.0**
Primary Electricity	1.0	1.6	2.2	1.2	1.3

Sources: ***IEO2001*:** Energy Information Administration (EIA), World Energy Projection System (2001). ***IEO2000*:** EIA, *International Energy Outlook 2000*, DOE/EIA-0484(2000) (Washington, DC, March 2000), Table A1, p. 169. **PEL:** Petroleum Economics, Ltd., *Oil and Energy Outlook to 2015* (London, United Kingdom, February 2000).

show similar expectations for growth in oil and natural gas use but different expectations for coal and nuclear power. In the *IEO2001* reference case, coal use is projected to increase by 1.0 percent per year, whereas the IEA and S&P projections are considerably higher, at 2.7 and 3.0 percent per year, respectively. Much of the future coal use in the *IEO2001* projection is offset by a more robust forecast for nuclear power than in either of the other two forecasts. *IEO2001* expects primary electricity use (nuclear power and renewable energy) to increase by 1.4 percent per year, compared with 1.0 percent per year in the IEA and S&P forecasts.

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Table 10. Comparison of World Energy Consumption Growth Rates by Fuel, 1997-2020
(Average Annual Percent Growth)

Fuel	*IEO2001* Low Growth	*IEO2001* Reference	*IEO2001* High Growth	*IEO2000*	S&P	IEA
Oil	1.4	2.2	2.9	1.9	2.1	1.9
Natural Gas	2.3	3.1	3.8	3.2	3.0	2.7
Coal	0.3	1.0	1.8	1.6	2.1	1.7
Nuclear	0.3	0.5	1.1	-0.3	—[a]	0.0
Renewable/Other	1.3	2.0	2.7	1.9	—[a]	2.3
Total	**1.3**	**2.1**	**2.8**	**2.1**	**2.3**	**2.0**
Primary Electricity[a]	0.9	1.4	2.1	1.1	1.0	1.0

[a]S&P reports nuclear and hydroelectric power together as "primary electricity."

Sources: ***IEO2001*:** Energy Information Administration (EIA), World Energy Projection System (2001). ***IEO2000*:** EIA, *International Energy Outlook 2000*, DOE/EIA-0484(2000) (Washington, DC, March 2000), Table A1, p. 169. **S&P:** Standard & Poor's Platt's, *World Energy Service: World Outlook 1999* (Lexington, MA, January 1999), p. 3. **IEA:** International Energy Agency, World Energy Outlook 2000 (Paris, France, November 2000), pp. 364-418.

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World Oil Markets

In the IEO2001 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.

Crude oil prices remained above $25 per barrel in nominal terms for most of 2000 and have been near $30 per barrel in the early months of 2001. Prices were influenced by the disciplined adherence to announced cutbacks in production by members of the Organization of Petroleum Exporting Countries (OPEC). OPEC's successful market management strategy was an attempt to avoid a repeat of the ultra-low oil price environment of 1998 and early 1999.

Three additional factors contributed to the resiliency of oil prices in 2000. First, oil companies were slow to commit capital to major oil field development efforts, fearing a return to low prices. Even a full year of robust prices did not significantly relax the industry's tight profitability standards, especially for riskier offshore, deepwater projects. Second, oil demand in the recovering economies of the Pacific Rim rebounded more rapidly than anticipated after their 1997-1999 recession. Third, oil companies were reluctant to refill abnormally low inventories, because they feared a return to the low price environment of 1998.

Oil consumption in 2000 rose by slightly less than 1 million barrels per day, with nonindustrialized nations accounting for all the increase. Oil demand in the developing economies of the Pacific Rim and China was responsible for about 50 percent of the increase. Although the developing Asian economies are no longer in recession, their current growth is modest by comparison with the rapid economic expansion in the region during the early and mid-1990s. Latin American oil demand also experienced only modest growth in 2000. Perhaps the most significant story in oil demand in 2000 is the former Soviet Union (FSU). For the first time in more than a decade, oil demand in the FSU grew slightly [***1***].

At their meeting on January 17, 2001, OPEC members (not including Iraq) agreed to cut back production quotas by a total of 1.5 million barrels per day, in response to indications of some demand weakness in the near-term market. Because some OPEC members were not producing at their previous quota levels, however, actual production is expected to be reduced by only 1 million barrels per day. It is anticipated that the cutbacks will keep the world oil price (refiner acquisition cost for imports) well within OPEC's target range of $22 to $28 per barrel throughout 2001, although additional production corrections are certainly possible. Prices are not expected to decline toward the lower end of the target range until 2002 or later. Iraq's oil production and exports have been falling off in response to Iraqi efforts to have United Nations sanctions lifted. Those efforts are assumed to continue throughout much of 2001.

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; and OPEC's consensus building is made easier as a result. However, non-OPEC production is expected to show significant increases in the near future, and several members of OPEC have announced plans to expand production capacity over the next several years. In an oil market environment where substantial spare capacity exists, it will be much more difficult for OPEC to achieve the unanimity among its members that dictates a successful market management strategy.

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 time between higher prices and increases in drilling activity seems to have increased in the aftermath of the low price environment, non-OPEC production increased by 1.2 million barrels per day in 2000 and is expected to increase by an additional 600 thousand barrels per day in 2001 and 800 thousand barrels per day in 2002. Almost 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 remain above $20 per barrel even when the production targets of OPEC producers are raised and significant increases in non-OPEC production are once again expected? Will sustained and robust economic growth in developing countries continue even in the face 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, that development is not indicative of the trend in the *International Energy Outlook 2001* (*IEO2001*) reference case. In the short term, oil prices are expected to continue at the levels seen during the later months of 1999 into 2000. As OPEC production cutbacks are relaxed and non-OPEC production increases over the next few years, oil prices are expected to fall back slightly from the 2000 level, then increase gradually out 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 120 million barrels per day by 2020, requiring an increment to world production capability of almost 43 million barrels per day relative to current capacity. OPEC producers are expected to be the major beneficiaries of increased production requirements, but non-OPEC supply is expected to remain highly competitive, with major increments to supply expected to come from offshore resources, especially in the Caspian Basin 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 in normal oil production and trading patterns. On the other hand, significant excursions from the reference price trajectory are not likely to be long sustained. High real prices deter consumption and encourage the emergence of significant competition from marginal but large sources of oil and 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 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 *IEO2001* low and high world oil price cases suggest tha 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.

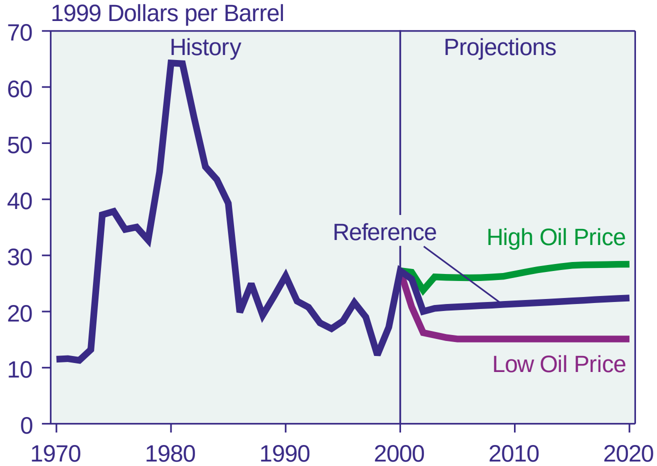
Highlights of the *IEO2001* projection for the world oil market are as follows:

- The reference case oil price projection shows declines of $1.50 per barrel in 2001, about $1 per barrel in 2002, and more than $4 per barrel in 2003, followed by a gentle 0.3-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 highly 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 *IEO2001* reference case projections are significant. Sustained economic recovery in developing Asia, Japan's economic turnaround, China's economic reforms and human rights record, trickle-down effects from Brazil to 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 *IEO2001* reference case is somewhat different from that in *IEO2000*. In last year's reference case price path, significant relief was expected in 2001 from the high oil prices of late 1999 and 2000, primarily because adherence to announced OPEC production cutbacks by member nations had a long history of being unsuccessful. This year's reference case price path shows prices above $25 per barrel through 2001, based on the assumption that OPEC will be able to manage the oil market effectively during the year but not after that. In both outlooks, the price trajectory in the

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



Sources: **History:** Energy Information Administration (EIA), *Annual Energy Review 1999*, DOE/EIA-0384(99) (Washington, DC, July 2000). **Projections:** 2000-2002—EIA, *Short-Term Energy Outlook*, on-line version (January 8, 2001), web site www.eia.doe.gov/emeu/steo/pub/contents.html. 2003-2020—EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000).

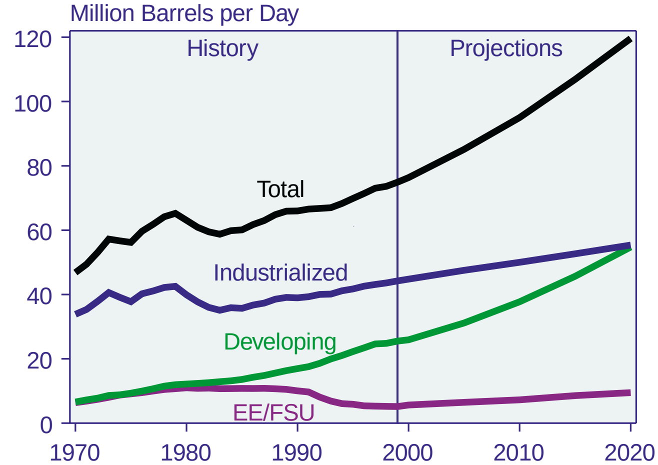
reference case beyond 2005 shows a gradual increase of about 0.3 percent per year out to 2010. Three possible long-term price paths are shown in Figure 24.

In all the *IEO2001* 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 as much as 52 million barrels per day. There is widespread agreement that resources are not a key constraint on world oil demand to 2020. Rather more important are the political, economic, and environmental circumstances that could shape developments in oil supply and demand.

World Oil Demand

Petroleum consumption is projected to grow by 44.7 million barrels per day in the *IEO2001* reference case, from 74.9 million barrels per day in 1999 to 119.6 million barrels per day in 2020 (Figure 25). The expected increment is 59 percent larger than the increment of 28.1 million barrels per day in worldwide oil use between 1970 and 1999. The growth in oil demand over the past three decades was tempered somewhat by declines in world oil demand after the oil shocks of 1973 and 1979. Since 1983, however, worldwide oil use has increased steadily. Demand is projected to increase at an average annual rate of 2.3 percent per year in the *IEO2001* reference case, as compared with the average of 1.6 percent per year over the past three decades.

Figure 25. 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, January 2001). **Projections:** EIA, World Energy Projection System (2001).

World oil demand growth slowed significantly between 1997 and 1998 when several countries, primarily in Asia and the FSU, posted declines in consumption. In Asia (excluding China) oil demand fell by more than 500 thousand barrels per day, and in the FSU demand fell by 100 thousand barrels per day. Total world oil demand rose by only 585 thousand barrels per day in 1998 over the previous year, which was about one-third of the average increase from 1993 to 1997. Turmoil in financial markets, beginning in southeast Asia but also spreading to Russia with the devaluation of the ruble in August 1998, led to marked slowdowns in economic growth, resulting in lower demand for energy in 1998.

Demand began to recover in 1999, as most of the Asian countries that had suffered from the economic recession that began in the spring of 1997 were in strong economic recovery. In addition, Russia and Ukraine, the largest economies of the FSU region, enjoyed their greatest economic performance since the collapse of the Soviet Union in the early 1990s. Although FSU oil use fell by about 50 thousand barrels per day in 1999, it recovered by 15 thousand barrels per day in 2000 as strong economic growth continued, propelled by domestic industrial growth and high world oil prices that benefited oil producers in the region. In Japan and the developing Asian countries (excluding China, where oil use continued to grow even while the rest of Asia was mired in recession), total oil use increased in 1999 by 200 thousand barrels per day and in 2000 by another 400 thousand barrels per day, despite the high oil price environment [*2*].

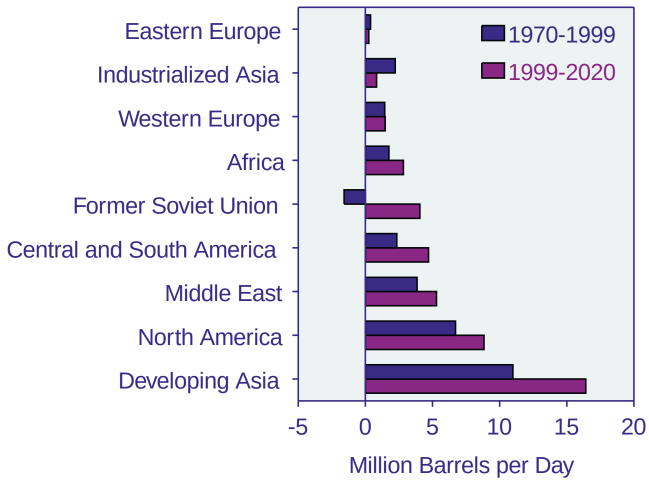
The industrialized countries continue to consume more of the world's petroleum products than do the developing countries, but the gap is projected to close significantly. By 2020, consumption in developing countries is expected to be nearly equal to that in the industrialized countries. The projected increase in oil use in the industrialized world is attributed mostly to the transportation sector, but projected growth in oil demand in the developing world is projected to occur in all end-use sectors. Developing countries are projected to account for 65 percent of the world's increment in oil use over the projection period.

Among the regions of the developing world, developing Asia is expected to show the largest increase in oil demand. Petroleum consumption is projected to rise by 16 million barrels per day over the next two decades (Figure 26), fueled by strong economic growth and increasing demand for personal motorization. After developing Asia, the Middle East (5.3 million barrels per day), Central and South America (4.7 million barrels per day), and the former Soviet Union (4.1 million barrels per day) are also projected to make significant contributions to the growth in world oil demand.

On a per capita basis, world oil consumption has remained flat since the mid-1980s (Figure 27), primarily because declines in per capita consumption in the FSU (caused by the economic collapse in the region after the dissolution of the Soviet Union in the 1990s) offset increases in the rapidly expanding economies of the developing world and, to a lesser extent, in the industrialized world. Per capita world oil consumption is expected to continue to rise steadily in the reference case, surpassing the levels of the 1970s by 2015. In contrast, however, the amount of oil consumed per unit of GDP is expected to decline (Figure 28) as increasing economic prosperity leads to more energy-efficient and less energy-intensive uses. Oil intensity peaked in 1973, and it is expected to decline to about half the 1973 level by 2020.

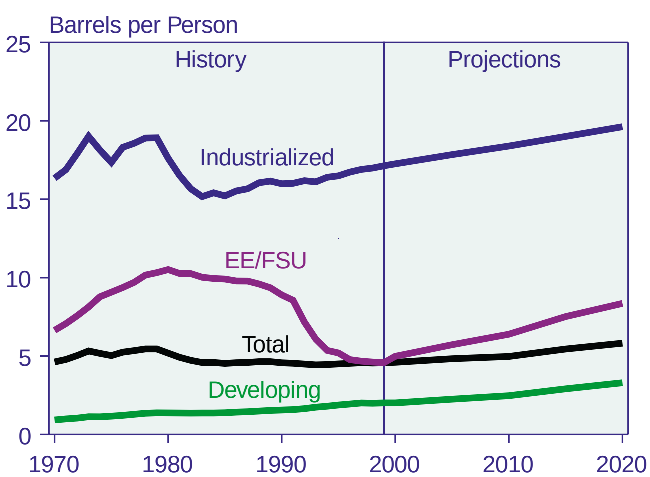
Petroleum consumption continues to grow most rapidly in the transportation sector. The decline in consumption in 1998 affected primarily the nontransportation uses of

Figure 26. Increments in Oil Consumption by Region, 1970-1999 and 1999-2020



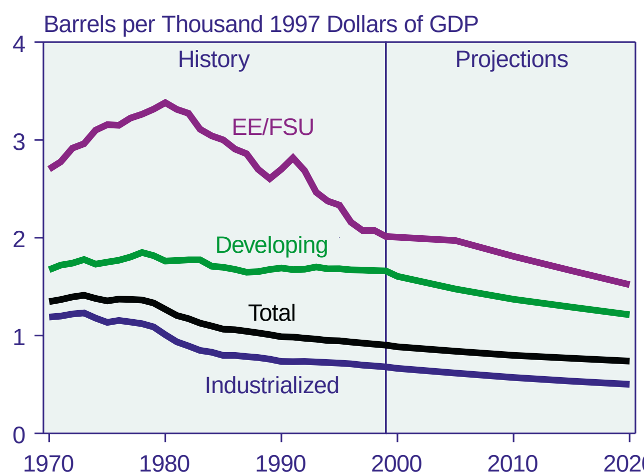
Sources: **1970 and 1999:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **2020:** EIA, World Energy Projection System (2001).

Figure 27. Oil Consumption per Capita 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, January 2001). **Projections:** EIA, World Energy Projection System (2001).

Figure 28. 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, January 2001). **Projections:** EIA, World Energy Projection System (2001).

petroleum, whereas oil consumed in the transportation sector increased by about the same amount as in each of the three previous years. Nontransportation oil consumption, on the other hand, declined in nearly all regions worldwide. As a result, petroleum use for transportation in 1998 equaled nontransportation uses for the first time. Figure 29 shows historical and projected petroleum consumption by sector in the industrialized and developing nations for selected years from 1980. Only the transport sector has shown a substantial increase from 1980. Of the 44.7 million barrels per day increase in the reference case forecast, 29.7 million barrels per day are projected to take place in the transportation sector.

Transportation consumption makes up nearly all of the projected increase in oil demand in the industrialized countries (Figure 29). In the developing countries, oil consumption for uses other than transportation is still larger than transport consumption and strong growth is expected to continue in these sectors. Transportation consumption in developing countries, however, is projected to outpace other uses so that, by 2020, consumption for transportation exceeds the total of all other uses.

Developing Asia

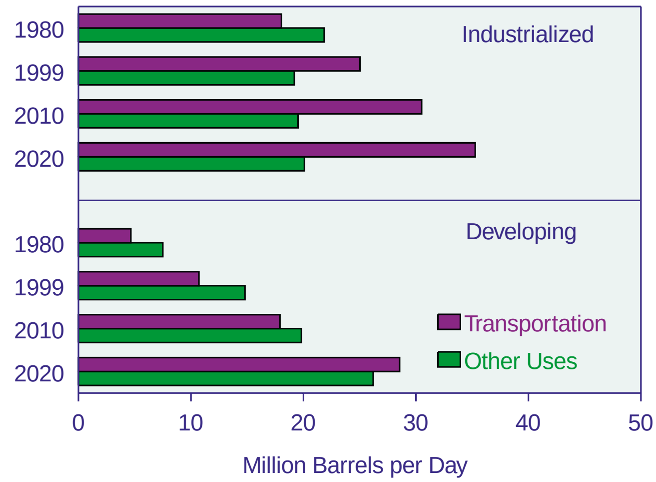
The largest increase in oil demand is projected for the developing countries of Asia, where consumption is expected to increase by 3.9 percent per year between 1999 and 2020 (Figure 30). This region alone is expected to account for 37 percent of the increase in world oil demand in the forecast period, the highest regional growth in the world. Strong expected economic growth in developing Asia fuels the demand for additional oil consumption, both in terms of increasing demand for transportation sector energy use and for other industrial, electricity sector, and building uses.

In China, the largest oil consumer in developing Asia, oil demand is projected to increase by 6.1 million barrels per day from 1999 to 2020. Much of the increment is expected in the transportation sector, where the need to transport people and goods will be increasingly important for economic growth. More than two-thirds of the increase in China's oil use is expected in the transportation sector, and the transportation share of the country's oil use is expected to increase from about one-third in 1999 to 55 percent in 2020.

While much of the motor vehicle population in China is owned by institutions (primarily the government), increasing wealth is expected to spur demand for personal motor vehicles that can be used for private travel. Already, there are signs that China's "newly rich" and small businesses that have succeeded as a result of increasing economic liberalization are starting to obtain private vehicles. The most dramatic example is the number of minivans being used by burgeoning taxi companies [*3*]. Moreover, China's trucking industry has increasingly been deregulated over the past decade, which should also encourage the growth of the transportation sector.

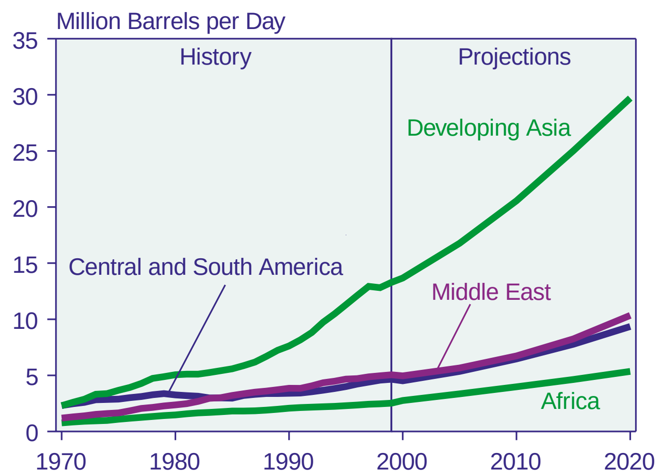
Nontransportation oil demand in China is projected to increase by an average of 2.4 percent per year—a faster growth rate than that for total oil demand in most industrialized countries. The industrial sector is expected to account for more than 40 percent of China's oil

Figure 29. Oil Consumption for Transportation and Other Uses in Industrialized and Developing Nations, 1980-2020



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

Figure 30. Oil Consumption in the Developing 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, January 2001). **Projections:** EIA, World Energy Projection System (2001).

consumption. In addition, China is one of the world's largest consumers of oil for chemical uses, and its chemical industry consumed about 13 percent of the petroleum used in China in 1997. Increases are also expected in other end-use sectors, including the electricity sector as China attempts to diversify away from its heavy reliance on coal.

From 1970 to 1999, oil consumption in South Korea grew at an average rate that was among the highest in the world. Despite a decline of 419 thousand barrels per day in 1998 and a modest increase of 67 thousand barrels per day in 1999, petroleum consumption grew at an average annual rate of 8.4 percent from 1970 to 1999, much of it attributed to substantial increases in personal motorization during the period. The projected growth rate in energy use slows markedly over the projection period as the transportation sector reaches saturation levels. Still, South Korea is expected to add 1.2 million barrels per day to world oil demand in the forecast period, only slightly less than Western Europe.

While the proportion of South Korea's transportation oil use increases slightly over the forecast years, nontransportation consumption is projected to account for 59 percent of the increase in oil demand from 1999 to 2020. As in Japan and China, the chemical industry in South Korea is a large user of oil, consuming about one-fifth of the total oil used. The residential and commercial sectors also make up a significant portion of South Korea's oil market.

India's oil demand is projected to rise from 1.9 million barrels per day in 1999 to 5.8 million barrels per day in 2020. At 5.4 percent per year, the projected growth rate for oil use in India is the highest among the countries and regions in the forecast. The transportation sector currently makes up half of the oil market in India, and 86 percent of the projected increase is expected to be used for transport. Although thus far the poor state of India's transportation infrastructure has constrained fast-paced growth in automobile ownership, rapid expansion of private motorization and of the corresponding demand for transportation fuels is expected to follow as the infrastructure improves. At present, automobile ownership in India is largely viewed as a symbol of emerging wealth. The industrial sector is the next largest user of oil with more than 10 percent of India's oil consumed by the chemical industry, although analysts expect that future growth in the chemical industry will be fueled by natural gas and electricity rather than oil [***4***].

IEO2001 also projects strong growth in petroleum consumption for the other developing countries in Asia. For the other Asia group, oil demand is expected to increase from 5.0 million barrels per day in 1999 to 10.2 million barrels per day in 2020, at an average rate of 3.5 percent per year. The transportation sector's share of oil demand for this group as a whole is expected to remain just below 50 percent throughout the forecast period.

The oil markets in the other Asia developing country group are diverse, as demonstrated by the three largest oil consumers, Indonesia, Taiwan, and Thailand. Oil consumed for transport in Indonesia leads other uses but makes up less than half the market. The industrial, residential, and power generation sectors are all significant oil users in Indonesia. In Taiwan, oil use for industry leads the other sectors, with a share of nearly 20 percent for the chemical industry alone; transportation consumption is slightly lower than industrial consumption; and oil use for power generation makes up more than 15 percent of total oil demand. The oil market in Thailand is dominated by the transportation sector, with industrial uses a distant second.

Middle East

The second largest increment in oil demand among the developing countries is expected for the Middle East. Oil consumption in the Middle East is projected to increase from 5.0 million barrels per day in 1999 to 10.3 million barrels per day in 2020, at an average rate of 3.5 percent per year. In Turkey (included in the Middle East projections), oil demand is projected to grow by 3.6 percent per year, to 1.3 million barrels per day in 2020. Much stronger growth is expected for nontransportation oil uses in Turkey than for the country's transportation sector. Industrial oil consumption in Turkey is nearly as high as oil use in the transportation sector, and its oil use for agriculture is considerably higher than the average for the Organization for Economic Cooperation and Development (OECD), of which Turkey is a member.

Saudi Arabia and Iran are the largest oil users among the other Middle East countries. Saudi Arabia consumed about 1.3 million barrels per day in 1999 and Iran 1.2 million barrels per day. Transportation sector oil consumption is projected to grow more rapidly than other oil use in the forecast period in the Middle East region, accounting for 57 percent of the expected increase, but growth is constrained by the fact that women, a sizable portion of the population, are not permitted to drive in a number of Middle Eastern countries. The residential and commercial sectors are also large oil users, and oil consumption for chemical uses is expected to increase as Saudi Arabia plans to expand its chemical industry [***5***].

Africa

Oil demand in Africa is projected to grow at an average annual rate of 3.6 percent, from 2.5 million barrels per day in 1999 to 5.4 million barrels per day in 2020. Although transportation demand in Africa is projected to nearly double from 1999 to 2020, it is expected to contribute less, on a percentage basis, to the overall increase than in any other region except the FSU. Africa's underdeveloped transportation infrastructure is expected to inhibit growth in oil use for transportation. The industrial sector consumes the most oil among Africa's nontransportation oil sectors, followed by power generation and the residential and commercial sectors. The proportion of oil used for power generation and in the residential and commercial sectors in Africa is similar to the average for non-OECD countries, which is much higher than in most of the industrialized countries.

Egypt and South Africa are the largest oil consumers in Africa. As in many countries, the transportation and industrial sectors are the largest users of oil in Egypt. In contrast to most other countries, however, a much larger share (about 20 percent) of petroleum is used for power generation in Egypt. In South Africa, the transportation sector consumes about 75 percent of the oil used, and virtually none is used for power generation.

Central and South America

The developing nations of Central and South America are projected to add 4.7 million barrels per day to world oil demand from 1999 to 2020, at an average annual growth rate of 3.4 percent. Relative to other non-OECD countries, transportation consumption tends to have a larger share of the region's oil market and power generation a smaller share.

In the countries outside of Brazil, oil consumption for nontransportation uses is expected to grow at 0.5 percent per year while transport oil demand is projected to rise at 4.5 percent per year. By 2020, two-thirds of the oil is projected to be consumed for transportation. Argentina and Venezuela are the largest oil consuming countries outside of Brazil. Argentina's large agricultural sector uses a relatively large share of petroleum products. Venezuela consumes more than 60 percent of its oil for transportation.

Brazil, at 2.0 million barrels per day in 1999, is by far the largest oil user in Central and South America. Brazil's oil consumption is projected to increase to 4.5 million barrels per day in 2020, at an average annual growth rate of 4.1 percent. Transportation consumption is projected to increase by 4.8 percent per year between 1999 and 2020. Brazil also has a relatively large chemical industry. Nontransportation oil demand is projected to increase at 3.4 percent per year from 1999 to 2020, a much faster pace than the Other Central and South America group.

North America

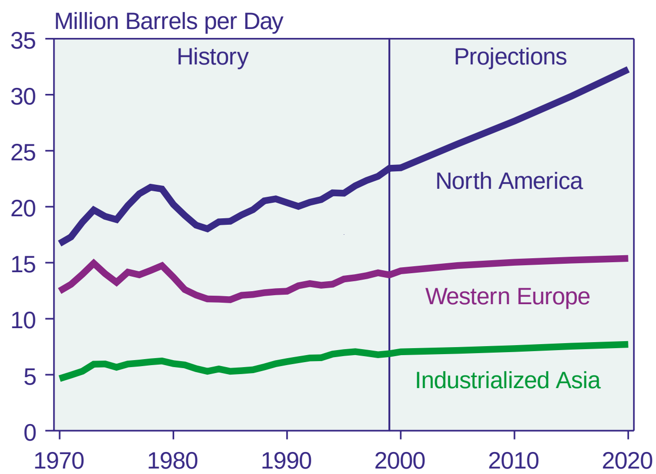
Petroleum product consumption in North America is projected to increase by 8.8 million barrels per day from 1999 to 2020, at an average annual growth rate of 1.5 percent. This is by far the largest expected increase among the industrialized regions (Figure 31), with projected increases of 6.3 million barrels per day in the United States, 2.2 million barrels per day in Mexico, and 0.3 million barrels per day in Canada.

Much of the increase in U.S. oil consumption is projected to occur in the transportation sector, which already accounts for two-thirds of U.S. petroleum use. In recent years, relatively low fuel prices and higher personal income have resulted in consumer demand for larger and more powerful vehicles. Further, vehicle fuel efficiency is not expected to improve as rapidly over the next two decades as it did in the 1980s. Fuel efficiency standards for light-duty vehicles (cars, vans, pickup trucks, and sport utility vehicles) are assumed to remain at current levels [***6***].

Oil use in the U.S. industrial sector currently accounts for 26 percent of the Nation's total oil use and is expected to increase from 5.2 million barrels per day in 1999 to 6.2 million barrels per day in 2020. Most of the increase is expected in the petrochemical, construction, and refining sectors [***7***]. Petroleum use for heating and for electricity generation is, in contrast, projected to decline over the forecast horizon as oil loses market share to natural gas. For electricity generation, oil-fired steam plants are being retired in favor of natural gas combined-cycle units.

Petroleum product consumption in the transportation sector in Mexico is projected to increase by 1.6 million barrels per day from 1999 to 2020, accounting for about 70 percent of the total expected increase in Mexico's oil demand. Mexico also consumes a much larger share of oil for power generation than do most other

Figure 31. 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, January 2001). **Projections:** EIA, World Energy Projection System (2001).

industrialized countries. Nearly one-fourth of the oil consumed in Mexico is for power generation, compared with about 5 percent for the OECD as a whole.[4] As a result, Mexico consumes a much larger proportion of residual fuel (about 25 percent in 1997) than most industrialized countries. Over the forecast period, however, the share of oil used for power generation is expected to decline as natural gas makes significant inroads in this sector [***8***]. With the fuel slate expected to become lighter in the future, plans are being considered to upgrade the Mexican refining sector in order to produce more light products and less residual fuel [***9***].

In Canada, virtually all the increase in oil consumption from 1999 to 2020 is expected to occur in the transportation sector. Canada's extensive hydroelectric and natural gas resources are widely used for power generation, industrial, and building uses. The North American Free Trade Agreement has largely unified the Canadian transportation sector with that of the United States. Although Canadian consumers are expected to follow U.S. trends in terms of demanding larger and more powerful motor vehicles over the forecast period, a much smaller Canadian population relative to the United States keeps the total projected increment in transportation fuel use in Canada at a modest 0.3 million barrels per day between 1999 and 2020.

Western Europe

Oil consumption in Western Europe is projected to increase by 1.5 million barrels per day from 1999 to 2020, at an average growth rate of 0.5 percent per year. Growth is expected mainly in the transportation sector, and the use of petroleum products in other sectors is projected to decline over the forecast period. Expanding access to natural gas is expected to lead to a decreasing share of oil in Western Europe's energy mix. The industrial sector is the largest nontransportation consumer of oil, with a substantial portion used by chemical industries; however, analysts expect that in many countries of Western Europe oil will also lose market share to natural gas in the industrial sector over the next two decades [***10***].

Germany is Western Europe's largest oil-consuming country, at 2.8 million barrels per day in 1999. Transportation consumption makes up nearly 50 percent of the total. Germany is Europe's largest user of oil as a feedstock for the chemical industry and, in addition, consumes a much larger proportion of oil for domestic uses in the residential and commercial sectors, where efforts to reduce coal consumption in East Germany's building sector after the reunification of the two Germanies in the early 1990s led to a switch from brown coal to heating oil.

The newest trend in upgrading the East German infrastructure is a move to replace oil with natural gas [***11***]. The share of petroleum product consumption in the residential and commercial sectors is nearly 25 percent, just slightly below that in the industrial sector, and is much larger than the 10-percent share for residential and commercial consumption for the OECD as a whole. Petroleum consumption outside the transportation sector in Germany is projected to decline slightly over the forecast period.

The second largest oil consumer in Western Europe is Italy. Nearly 60 percent of Italy's oil use is outside the transportation sector, a much larger proportion than in most other European countries. Oil use in the industrial sector makes up about one-fourth of Italy's total petroleum consumption, as does the electricity generation sector; however, natural gas is projected to take on an increasingly important role in the country's energy markets as it attempts to diversify away from heavy reliance on petroleum. Italy has worked to establish a natural gas distribution network that already reaches most Italian cities with a potential for district heating [***12***], and natural gas is now the dominant fuel in the building sector. As a result, nontransportation oil demand is projected to remain essentially flat in Italy from 1999 to 2020, while transportation sector oil use increases by 0.6 percent per year.

Industrialized Asia

Oil demand in industrialized Asia is projected to grow at an average annual rate of 0.5 percent over the forecast period, considerably less than the average increase of 1.4 percent per year from 1970 to 1999. Less than 1 million barrels per day is expected to be added to the region's petroleum consumption.

Japan is the second largest oil-consuming country in the world, and its demand for petroleum products is projected to increase by about 350 thousand barrels per day from 1999 to 2020, at an average growth rate of 0.3 percent per year. The transportation sector's share of the oil market, at 35 percent, is the lowest among the industrialized countries. Japan uses a much larger proportion of oil to power the industrial sector than does the United States or the OECD as a whole, mostly because Japan does not have easy access to natural gas or coal. Power generation in Japan also has a larger share of the oil market than in most other industrialized countries. Nevertheless, about 82 percent of the increase in the forecast period is projected for the transportation sector.

Australasia—dominated by Australia but also including New Zealand and the U.S. Territories—is projected to have a much higher growth rate in oil consumption than

[4]Calculations based on International Energy Agency statistics.

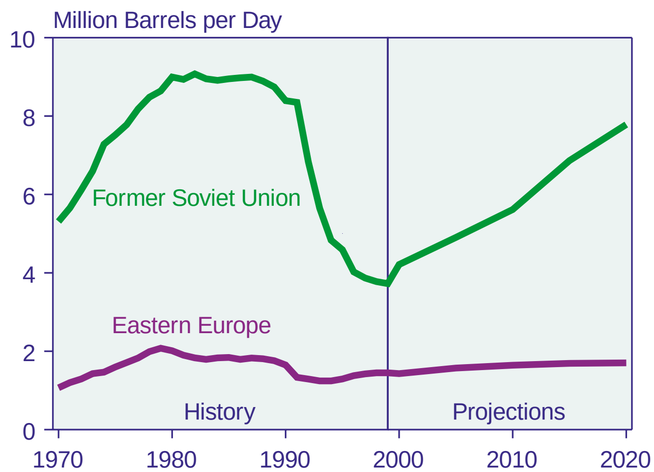
is Japan. Australia, in particular, is a geographically large country with a widespread population, and its transportation sector is projected to account for the largest increment in petroleum consumption over the forecast period. Motorization levels are high in Australasia at 642 vehicles per thousand persons, as compared with 569 vehicles per thousand in Japan, and they are projected to reach saturation levels by the end of the projection period.

Eastern Europe and the Former Soviet Union

The economic and political collapse of the Soviet Union in the early 1990s caused petroleum consumption in the FSU region to fall sharply in the 1990s, to 3.7 million barrels per day in 1999, after having risen to more than 9 million barrels per day in the early 1980s (Figure 32). As economic recovery in the FSU continues, oil demand is projected to increase to 7.8 million barrels per day in 2020. Nontransportation uses are expected to make up about 71 percent of the increase. Russia, which consumed about 64 percent of the FSU total in 1999, uses relatively large proportions of oil for agriculture and power generation.

Oil demand in Eastern Europe has also fallen sharply from the levels of the 1980s although not as severely as in the FSU. Petroleum consumption was 1.5 million barrels per day in 1999 and is projected to rise to 1.7 million barrels per day in 2020, remaining well below the peak of 2.1 million barrels per day in 1979. The economies of Eastern Europe have largely been in recovery since the mid-1990s, and their oil use is expected to grow by 0.8 percent per year on average between 1999 and 2020—a more rapid rate than is projected for Western Europe.

Figure 32. EE/FSU 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, January 2001). **Projections:** EIA, World Energy Projection System (2001).

Oil demand in Eastern Europe's transportation sector is projected to increase by 2.6 percent per year, and nontransportation uses are expected to decline in the forecast period.

Poland and Romania are the largest oil-consuming countries in Eastern Europe. About half of the oil consumed in Poland is used for transportation. Agriculture also has a relatively large proportion of the oil market. In contrast, Romania's transportation sector is much smaller, and nearly one-third of its oil consumption is for electricity generation.

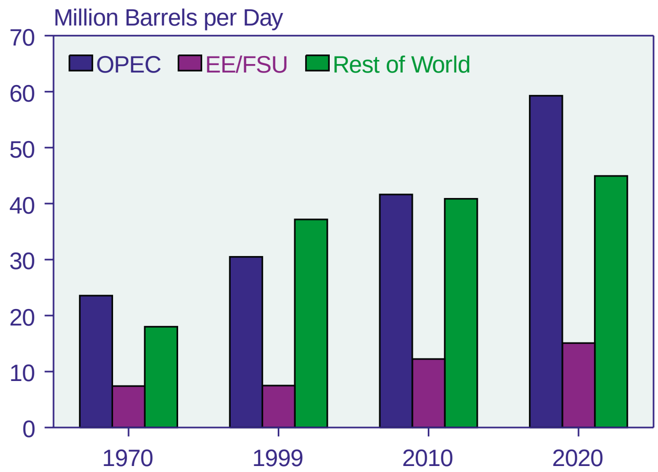
The Composition of World Oil Supply

The *IEO2001* reference case projects an increase in world oil supply of 45 million barrels per day over the projection period. Gains in production are expected for both OPEC and non-OPEC producers; however, less than one-third of the production rise is expected to come from non-OPEC areas. Over the past two decades, the growth in non-OPEC oil supply has 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 [***13***].

The reference case projects that more than 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 30 million barrels per day higher than it was in 1999 (Figure 33). The *IEO2001* estimates of OPEC production capacity out to 2005 are slightly less than those projected in *IEO2000*, reflecting a shift toward non-OPEC supply projects in the current 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 support such suggestions.

Figure 33. World Oil Production in the Reference Case by Region, 1970, 1999, 2010 and 2020



Sources: **History:** Energy Information Administration (EIA), *International Petroleum Monthly*, DOE/EIA-0520(2000/12) (Washington, DC, December 2000). **Projections:** EIA, World Energy Projection System (2001).

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 *IEO2001* reference case, the production call on OPEC suppliers is projected to grow at a robust annual rate of 3.4 percent (Table 11 and Figure 34). 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.

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 the United Nations Security Council resolutions. The expansion was required because of the low price environment of early 1999. In the *IEO2001* reference case, Iraq is assumed to maintain its current oil production capacity of 3.1 million barrels per day into 2001, and its exports are assumed to average between 1.5 and 1.7 million barrels per day. The Security Council sanctions are assumed to remain in place through 2002. 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.

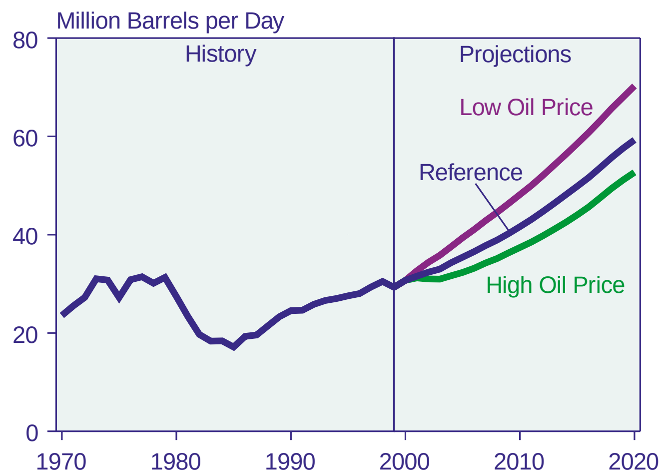
Table 11. OPEC Oil Production, 1990-2020
(Million Barrels per Day)

Year	Reference Case	High Oil Price	Low Oil Price
History			
1990	24.5	—	—
1999	29.3	—	—
Projections			
2005	35.4	32.3	39.4
2010	41.6	37.4	48.2
2015	49.9	44.0	58.5
2020	59.3	52.7	70.3

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

Sources: **History:** Energy Information Administration (EIA), *International Petroleum Monthly*, DOE/EIA-0520(2000/12) (Washington, DC, December 2000), Table 1.4. **Projections:** EIA, World Energy Projection System (2001).

Figure 34. OPEC Oil Production in Three Oil Price Cases, 1970-2020



Sources: **History:** Energy Information Administration (EIA), *International Petroleum Monthly*, DOE/EIA-0520(2000/12) (Washington, DC, December 2000). **Projections:** EIA, World Energy Projection System (2001).

Given the requirements for OPEC production capacity expansion implied by the *IEO2001* 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 exceeding 85 years, substantial capacity expansion clearly is feasible.

Production costs in Persian Gulf OPEC nations are less than $1.50 per barrel, and the capital investment required to increase production capacity by 1 barrel per day is less than $5,000 [***14***]. Assuming the *IEO2001* low price trajectory, total development and operating costs over the entire projection period, expressed as percentage of gross oil revenues, would be less than 20 percent. Thus, Persian Gulf OPEC producers can expand capacity at a cost that is a relatively small percentage of projected gross revenues.

For OPEC producers outside the Persian Gulf, the cost to expand production capacity by 1 barrel per day is considerably greater, exceeding $10,000 in some member nations. However, even this group of producers can still expect margins in excess of 35 percent on investments to expand production capacity over the long term, even in the low price case [***15***]. Venezuela has the greatest potential for capacity expansion and could aggressively increase its production capacity to 4.6 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-D10 in Appendix D show the ranges of production potential for both OPEC and non-OPEC producers.

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

In the *IEO2001* forecast, OPEC members outside the Persian Gulf region are expected to increase their production potential substantially, despite their higher capacity expansion costs. There is much optimism regarding Nigeria's offshore production potential, although it is unlikely to be developed until the middle to late part of this decade. In addition, increased optimism about the production potential of Algeria, Libya, and Venezuela supports the possibility of reducing the world's dependence on Persian Gulf oil.

Non-OPEC Supply

The growth in non-OPEC oil supplies played a significant role in the erosion of OPEC's market share over the past 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 into the 1980s, and much of the new production in the 1990s has come from the developing countries of Latin America, the non-OPEC Middle East, and China. In the *IEO2001* reference case, non-OPEC supply from proven reserves is expected to increase steadily, from 44.6 million barrels per day in 1999 to 60 million barrels per day in 2020 (Table 12).

There are several important differences between the *IEO2001* production profiles and those published in *IEO2000*:

- The U.S. production decline is slightly less severe in the *IEO2001* projections as a result of higher near-term oil prices and technological advances and lower costs for deep exploration and production in the Gulf of Mexico.
- The resilient near-term oil prices coupled with enhanced subsea and recovery technologies delay the *IEO2000* estimated peak for North Sea production to 2005-2006 and slightly tempers the production decline out to 2020.
- Resource development in the Caspian Basin region was expected to be delayed significantly in the *IEO2000* forecast due to the prospects of a prolonged low price environment. In *IEO2001*, Caspian output is expected to rise to almost 2.8 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.
- *IEO2000* anticipated significant delays in exploration and development activities for deepwater projects worldwide. Significant output from such projects was not anticipated until oil prices returned to and remained in the $20 to $25 per barrel range for a significant period. With the current resiliency in prices, 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 *IEO2001* forecast by 1 to 2 years.

Table 12. Non-OPEC Oil Production, 1990-2020
(Million Barrels per Day)

Year	Reference Case	High Oil Price	Low Oil Price
History			
1990	42.2	—	—
1999	44.6	—	—
Projections			
2005	49.4	50.5	48.2
2010	53.1	54.4	51.2
2015	56.7	58.6	54.3
2020	60.0	62.0	57.2

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(2000/12) (Washington, DC, December 2000), Table 1.4. **Projections:** EIA, World Energy Projection System (2001).

In the *IEO2001* forecast, North Sea production reaches a peak in 2006, at almost 6.6 million barrels per day. Production from Norway, Western Europe's largest producer, is expected to peak at about 3.7 million barrels per day in 2004 and then gradually decline to about 3.1 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 is expected to produce about 3.1 million barrels per day by the middle of this decade, followed by a decline to 2.7 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 175,000 barrels per day, with only a gradual production decline anticipated beyond 2005. Current oil production in Yemen could increase by at least 120,000 barrels per day within the next couple of years, and those levels would 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 260,000 barrels per day. Vietnam is still viewed with considerable optimism regarding long-term production potential although exploration activity has been slower than originally anticipated. Output levels from Vietnamese fields are expected to exceed 400,000 barrels per day by 2020.

Australia has made significant recent additions to its proven reserves and is likely to 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 around 825,000 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 forecast period. Exploration and test-well activity have pointed to some production potential for Bangladesh and Mongolia, but significant output is not expected until the middle of 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 has somewhat 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 little 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 100,000 barrels per day over the next 2 years, and by the middle of the decade it could possibly 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 offshore 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 300,000 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. 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.

In North America, falling U.S. output is expected to be more than offset by production increases in Canada and Mexico. Canada's projected output 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 150,000 barrels per day at its peak sometime in the next several years. Canada is projected to add an additional 600,000 barrels per day in output from a combination of frontier area offshore projects and oil from tar sands. Higher near-term prices, technological advances, and lower costs for deepwater exploration and production in the Gulf of Mexico temper the projected decline in U.S.

production. Mexico is expected to adopt energy policies that encourage the efficient development of its vast resource base. Expected production volumes in Mexico exceed 4 million barrels per day by the end of the decade and show little decline out to 2020.

With the resiliency in near-term oil prices, oil production in the FSU is expected to reach 9.6 million barrels per day by 2005—a level that could be significantly 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 *IEO2001* reference case shows FSU output exceeding 14.7 million barrels per day by 2020, implying export volumes exceeding 8 million barrels per day. In China, oil production is projected to decline to 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 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 undiscovered resources. For the purpose of the three *IEO2001* price cases, no more than 15 percent of the mean United States Geological Survey estimate of undiscovered oil was allowed to be developed over the forecast period. Tables D1-D10 in Appendix D show the ranges of production potential for both OPEC and non-OPEC producers.

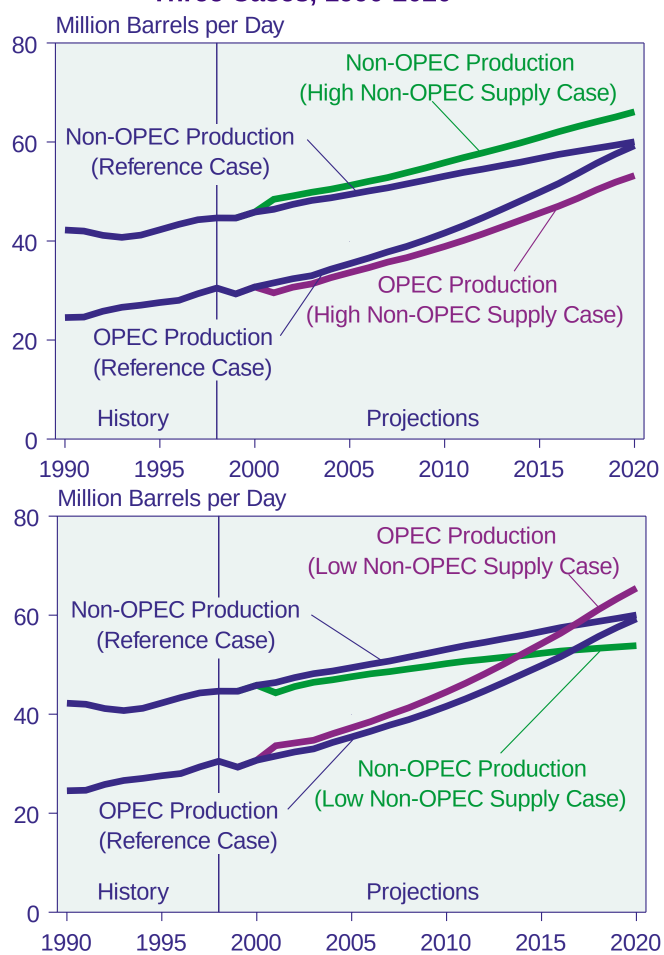
The expectation in the late 1980s and early 1990s was that non-OPEC production in the longer term would be stagnant or decline gradually in response to resource constraints. The relatively insignificant cost of developing oil resources within OPEC countries (especially those in the Persian Gulf region) 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 million barrels per day between 1993 and 2000.

It is expected that non-OPEC producers will continue to increase output, producing an additional 8.5 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.

Alternative Non-OPEC Supply Cases

The only variable affecting the estimates of non-OPEC production potential in the three *IEO2001* world oil price cases is the price assumption. As a result, the range of projected non-OPEC supply is modest, varying by only slightly less than 4.8 million barrels per day by the end of the forecast period. In fact, improved technology and a better understanding of the underlying resource potential have been major factors sustaining non-OPEC supply in the recent past. To examine the effects of those factors, two additional cases—the high and low non-OPEC supply cases—were developed. Figure 35 compares OPEC and non-OPEC production estimates in the reference case with those in the two alternative non-OPEC supply cases. The alternative cases used reference case assumptions except for the following departures.

Figure 35. OPEC and Non-OPEC Oil Production in Three Cases, 1990-2020



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

High Non-OPEC Supply Case:

- Due to increased optimism regarding the offshore production potential in the FSU, Latin America, West Africa, and the South China Sea, undiscovered oil in those regions is assumed to be 15 percent greater than the estimates in the reference case.
- One-third of the world's (non-OPEC, non-U.S.) undiscovered oil is considered economical to develop over the forecast period.
- Technology improvements over the forecast period are assumed to be transferrable worldwide.
- A reserve-to-production ratio of 15 years (slightly less than the current non-OPEC ratio) is used as a lower bound for production estimates.

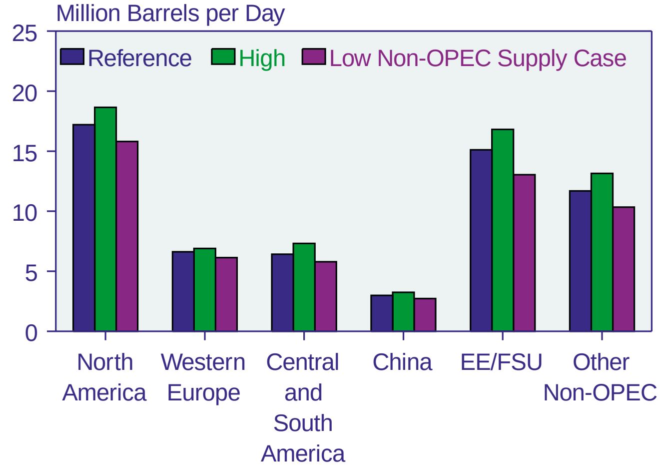
Low Non-OPEC Supply Case:

- The amount of oil production from undiscovered reserves in deepwater areas is assumed to be 25 percent less than the reference case estimate as a result of persistent low oil prices and the finding of more natural gas deposits than oil deposits.
- Only one-fifth of the undiscovered oil in non-OPEC areas is considered economical to develop over the forecast period.
- There are assumed to be no significant technology improvements over the forecast period, and worldwide oil recovery rates are assumed to average only 35 percent.
- There are assumed to be no significant technology improvements over the forecast period, and worldwide oil recovery rates are assumed to average only 35 percent. The reference case assumes a gradual increase in worldwide recovery rates to 45 percent by 2020.
- Russia's oil production is assumed to be one-third of that estimated in the reference case.

The high non-OPEC supply case assumptions result in a projection of 1.8-percent annual growth in non-OPEC production over the forecast period, as compared with a 1.4-percent growth rate in the reference case. Non-OPEC oil production reaches 66.1 million barrels per day in the high case in 2020, compared with 60 million barrels per day in the reference case. Figure 36 compares production levels for six non-OPEC regions in the reference, high non-OPEC supply, and low non-OPEC supply cases.

In the reference case, OPEC production reaches 59.3 million barrels per day, and the OPEC share of worldwide production reaches almost 50 percent by 2020. In the high non-OPEC supply case, OPEC production rises to 53.2 million barrels per day and never assumes a market share above 45 percent. The low non-OPEC supply case

Figure 36. Non-OPEC Oil Production by Region in Three Cases, 2020



Source: Energy Information Administration, World Energy Projection System (2001).

projects only a modest 0.9-percent annual growth for non-OPEC production over the forecast period. Non-OPEC production rises to 53.9 million barrels per day in 2020. OPEC production reaches 65.4 million barrels per day in 2020, with a 59-percent majority share of the world market.

Worldwide Petroleum Trade in the Reference Case

In 1998, industrialized countries imported 16.9 million barrels of oil per day from OPEC producers. Of that total, 10.3 million barrels per day came from the Persian Gulf region. Oil movements to industrialized countries represented more than two-thirds of the total petroleum exported by OPEC member nations and more than 63 percent of all Persian Gulf exports (Table 13). By the end of the forecast period, OPEC exports to industrialized countries are estimated to be about 5.7 million barrels per day higher than their 1998 level, and more than half the increase is expected to come from the Persian Gulf region.

Despite such a substantial increase, the projected share of total petroleum exports in 2020 that goes to the industrialized nations is considerably lower than their 1998 share, slightly over 50 percent. Their share of all Persian Gulf exports falls even more dramatically, to almost 38 percent. This significant shift 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 18.6 million barrels per day over the forecast period, with more than half the increase going to the developing countries of Asia. China, alone, will most

Table 13. Worldwide Petroleum Trade in the Reference Case, 1998 and 2020
(Million Barrels per Day)

Exporting Region	Importing Region: Industrialized: North America	Western Europe	Asia	Total	Nonindustrialized: Pacific Rim	China	Rest of World	Total
1998								
OPEC								
Persian Gulf	2.2	4.0	4.1	**10.3**	4.2	0.4	1.3	**5.9**
North Africa	0.4	2.0	0.0	**2.4**	0.0	0.0	0.1	**0.1**
West Africa	0.8	0.5	0.0	**1.3**	0.1	0.0	0.1	**0.2**
South America	1.8	0.2	0.0	**2.0**	0.1	0.0	0.9	**1.0**
Asia	0.1	0.0	0.8	**0.9**	0.1	0.0	0.0	**0.1**
Total OPEC	**5.2**	**6.7**	**5.0**	**16.9**	**4.6**	**0.4**	**2.4**	**7.4**
Non-OPEC								
North Sea	0.7	5.6	0.0	**6.3**	0.0	0.0	0.0	**0.0**
Caribbean Basin	2.4	0.5	0.0	**3.0**	0.2	0.0	2.1	**2.3**
Former Soviet Union	0.0	2.6	0.0	**2.7**	0.1	0.0	0.1	**0.2**
Other Non-OPEC	2.7	2.0	0.5	**5.2**	7.7	0.5	1.3	**9.5**
Total Non-OPEC	**5.8**	**10.7**	**0.6**	**17.1**	**8.0**	**0.5**	**3.5**	**12.0**
Total Petroleum Imports	**11.0**	**17.4**	**5.5**	**34.0**	**12.6**	**0.9**	**5.9**	**19.3**
2020								
OPEC								
Persian Gulf	4.7	3.7	4.8	**13.2**	8.2	5.3	8.3	**21.8**
North Africa	0.5	2.6	0.0	**3.0**	0.1	0.0	0.6	**0.8**
West Africa	0.9	1.2	0.3	**2.4**	0.1	0.0	1.1	**1.2**
South America	3.2	0.5	0.1	**3.8**	0.2	0.0	1.9	**2.1**
Asia	0.1	0.0	0.1	**0.2**	0.2	0.0	0.0	**0.2**
Total OPEC	**9.4**	**7.9**	**5.4**	**22.6**	**8.9**	**5.3**	**11.9**	**26.0**
Non-OPEC								
North Sea	0.7	5.1	0.0	**5.8**	0.1	0.0	0.0	**0.1**
Caribbean Basin	4.3	0.4	0.1	**4.8**	0.2	0.0	2.1	**2.2**
Former Soviet Union	0.4	4.4	0.2	**5.0**	3.6	0.6	0.2	**4.4**
Other Non-OPEC	3.2	2.0	0.2	**5.4**	7.7	0.8	1.5	**10.0**
Total Non-OPEC	**8.5**	**12.0**	**0.5**	**21.0**	**11.6**	**1.4**	**3.8**	**16.8**
Total Petroleum Imports	**18.0**	**19.8**	**5.9**	**43.7**	**20.4**	**6.7**	**15.7**	**42.8**

Notes: Totals may not equal sum of components due to independent rounding.
Sources: **1998:** Energy Information Administration (EIA), Energy Markets and Contingency Information Division. **2020:** EIA, Office of Integrated Analysis and Forecasting, IEO2001 WORLD Model run IEO01.B20 (2001).

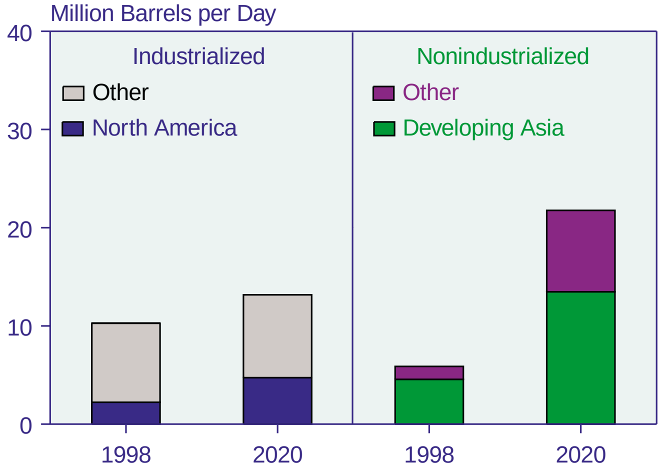
likely import about 5.3 million barrels per day from OPEC by 2020, virtually all of which is expected to come from Persian Gulf producers.

North America's petroleum imports from the Persian Gulf are expected to more than double over the forecast period (Figure 37). At the same time, more than half of total North American imports in 2020 are expected to be from Atlantic Basin producers and refiners, with significant increases in crude oil imports anticipated from Latin American producers, including Venezuela, Brazil, Colombia, and Mexico. West African producers, including Nigeria and Angola, are also expected to increase their export volumes to North America. Caribbean Basin refiners are expected to account for most of the increase in North American imports of refined products.

With a moderate decline in North Sea production, Western Europe is expected to import increasing amounts from Persian Gulf producers and from OPEC member nations in both northern and western Africa. Substantial imports from the Caspian Basin are also expected. Industrialized Asian nations are expected to increase their already heavy dependency on Persian Gulf oil. The developing countries of the Pacific Rim are expected to increase their total petroleum imports between 1998 and 2020 by almost 62 percent.

Worldwide crude oil distillation refining capacity was about 80.3 million barrels per day at the beginning of 1999. To meet the projected growth in international oil demand in the reference case, worldwide refining capacity would have to increase by more than 45 million

Figure 37. Imports of Persian Gulf Oil by Importing Region, 1998 and 2020



Sources: **1998:** Energy Information Administration (EIA), Energy Markets and Contingency Information Division. **2020:** EIA, Office of Integrated Analysis and Forecasting, IEO2001 WORLD Model run IEO01.B20 (2001).

barrels per day by 2020. Substantial growth in distillation capacity is expected in the Middle East, Central and South America, and especially in the Asia Pacific region. Refiners in North America and Europe, while making only modest additions to their distillation capacity, are expected to continue improving product quality and enhancing the usefulness of the heavier portion of the barrel through investment in downstream capacity. Likewise, future investments by developing countries are also expected to include more advanced configurations designed to meet the anticipated increase in demand for lighter products, especially transportation fuels.

Other Views of Prices and Production

Several oil market analysis groups produce world oil price and production forecasts. Table 14 compares the *IEO2001* world oil price projections with similar forecasts from Standard & Poor's Platt's (S&P), the International Energy Agency (IEA), Petroleum Economics, Ltd. (PEL), Petroleum Industry Research Associates (PIRA), the Gas Research Institute (GRI), National Resources Canada (NRCan), WEFA Energy (WEFA), and Deutsche Banc Alex.Brown (DBAB).

The collection of forecasts includes a wide range of price projections. The volatility of world oil prices in the late 1990s has helped to define this wide range with differing views about whether oil prices will sustain the higher levels achieved in 1999 given the recovery of many southeast Asian economies and the production quotas achieved by the OPEC member countries in 1999-2000. Prices for 2005 range from PEL's $15.63 per barrel (constant 1999 U.S. dollars) to PIRA's $22.56 per barrel. It is interesting to note that NRCan forecast was formulated in 1997 (but reaffirmed in 2000). While the forecast from NRCan formed the upper limit in last year's range of forecasts for 2005, this year, after a year of sustained world oil prices above $25 per barrel, the NRCan forecast falls within the range of the other forecasts.

IEO2001 expects oil prices to decline from the high rates of 2000 to $20.83 in 2005. This projection leans somewhat toward the higher end of the forecasts: only NRCan and PIRA project higher world oil prices in 2005. Recent forecasts from S&P, DBAB, IEA, and GRI all expect that prices will be in the lower range of $17 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 below those of the *IEO2001* low price path in 2010 and 2015, when the PEL time series ends. Even in 2005, the PEL projection is close to the *IEO2001* low price case projection of $15.10. If the PEL series is omitted, the range of prices among the remaining series is much smaller in 2015, $4.55 per barrel, with *IEO2001* at the high end of the range ($21.89 per barrel) and DBAB at the low end ($17.34 per barrel).

The *IEO2001* forecast tends to have higher prices than the other forecasts. Indeed, *IEO2001* prices are the highest of any other series across the 2005-2020 time period, with the exception of NRCan in 2005 and IEA in 2020. It should be noted that IEA did not publish a price value for 2015 in its *World Energy Outlook 2000*, however, it states that "between 2010 and 2020, the price increases steadily," from $19.83 dollars per barrel to $27.04 dollars per barrel. A simple interpolation results in an oil price in 2015 in excess of $23 per barrel, placing the IEA price assumption above the *IEO2001* estimate of $21.89 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 this year about EE/FSU production development than they were last year.

Higher world oil prices and a quickening economic recovery in Russia, the largest oil producer in the region currently, no doubt have influenced the production forecasts for the EE/FSU. Nevertheless, the share of EE/FSU production is not expected to rise above 13 percent of total world production in any of the forecasts (Table 15). S&P is the least optimistic about recovery in the region, and its projection never exceeds 8 percent. In

Table 14. Comparison of World Oil Price Projections, 2005-2020
(1999 Dollars per Barrel)

Forecast	2005	2010	2015	2020
IEO2001				
Reference Case	20.83	21.37	21.89	22.41
High Price Case	26.04	26.66	28.23	28.42
Low Price Case	15.10	15.10	15.10	15.10
S&P (October 2000)	19.47	18.65	19.87	21.16
IEA (November 2000)	19.83	19.83	—	27.04
PEL (February 2000)	15.63	13.77	11.75	—
PIRA (October 2000)	22.56	23.58	—	—
WEFA (February 2000)	18.39	18.48	19.42	20.41
GRI (January 2000)	18.17	18.17	18.17	—
NRCan (April 1997)	21.24	21.24	21.24	21.24
DBAB (January 2001)	17.08	16.98	17.34	17.68

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: ***IEO2001*:** Energy Information Administration, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000). **S&P:** Standard & Poor's Platt's, *U.S. Energy Outlook, Spring/Summer 2000* (Lexington, MA, October 2000). **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, February 2000). **PIRA:** PIRA Energy Group, *Retainer Client Seminar* (New York, NY, October 2000), Table II-3. **WEFA:** WEFA Group, *U.S. Energy Outlook 2000* (Eddystone, PA, February 2000), p. 1.17. **GRI:** Gas Research Institute, *2000 Data Book of the GRI Baseline Projections of U.S. Energy Supply and Demand to 2015*, Vol. 1 (Washington, DC, January 1999), p. SUM-21. **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 (January 9, 2001).

fact, S&P's forecast of Russia's share of world oil production (oil production estimates for the entire region are not available from S&P) falls to 7 percent in 2010 and still further, to 6 percent, at the end of the projection period. *IEO2001* and DBAB are the most optimistic forecasts for the region, with the EE/FSU share of world oil production reaching 12 percent and 11 percent, respectively, in 2005 and rising to 13 percent and 12 percent in 2010 and to 13 percent in both forecasts for 2015 and 2020.

The forecasts that provide projections through 2020 (*IEO2001*, S&P, DBAB, and IEA) all expect OPEC to provide incremental production of between 20 and 30 million barrels per day between 1997 and 2020 (Table 15).[5] There is more variation in expectations among these four forecast services for the "other" non-OPEC suppliers. S&P expects a substantial increase of 15 million barrels per day of supply from other suppliers, whereas IEA expects a decline in production from these sources of 0.8 million barrels per day. 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. *IEO2001* and DBAB expect more moderate growth from "other" non-OPEC supply, at 7 to 9 million barrels per day from 1997 to 2020.

References

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3. Standard & Poor's Platt's, *World Energy Service: Asia/Pacific Outlook 1999* (Lexington, MA, 1999), p. 54.
4. Standard & Poor's Platt's *World Energy Service: Asia/Pacific Outlook 1999* (Lexington, MA, 1999), p. 83.
5. Standard and Poor's Platt's *World Energy Service, Africa/Middle East* (Lexington, MA, 1999), p. 233.
6. Energy Information Administration, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), p. 67.
7. Energy Information Administration, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), p. 90.

[5]The comparisons use 1997 as a base year rather than 1998 or 1999, because the latest historical year of data available in IEA's *World Energy Outlook 2000* is 1997. Because there is some small variation between historical estimates, the oil production increments are calculated separately for each forecast.

Table 15. Comparison of World Oil Production Forecasts

Forecast	Percent of World Total			Million Barrels per Day			
	OPEC	EE/FSU	Rest of World	OPEC	EE/FSU	Rest of World	Total
History							
1997	39	10	50	28.3	7.3	36.1	**71.8**
Projections							
2005							
IEO2001	42	12	47	35.4	9.9	39.5	**84.8**
S&P[a]	44	8	45	38.0	6.6	38.6	**86.4**
PEL	42	9	46	36.3	8.1	39.6	**85.9**
PIRA	37	11	52	31.8	9.4	44.2	**85.4**
DBAB	42	11	45	36.0	9.2	37.9	**85.1**
2010							
IEO2001	44	13	43	41.6	12.2	40.9	**94.7**
S&P[a]	46	7	44	44.5	6.8	41.9	**95.1**
IEA[b]	46	11	38	44.1	10.3	36.6	**95.9**
PEL	46	9	42	44.2	8.9	40.2	**95.4**
PIRA	38	12	50	35.9	11.5	46.7	**94.1**
DBAB	45	12	40	43.1	11.4	38.5	**95.1**
2015							
IEO2001	47	13	40	49.9	13.9	42.8	**106.6**
S&P[a]	47	7	43	50.0	7.3	46.4	**107.5**
PEL	51	10	38	53.5	10.1	39.9	**105.8**
DBAB	47	13	38	49.3	13.2	40.2	**105.1**
2020							
IEO2001	50	13	38	59.3	15.1	44.9	**119.3**
S&P[a]	46	6	44	54.1	7.6	51.3	**116.6**
IEA[b]	54	11	29	61.8	12.3	33.8	**114.7**
DBAB	48	13	36	56.0	15.3	42.5	**116.5**

[a]In the S&P 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, S&P, 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: ***IEO2001*:** Energy Information Administration, World Energy Projection System (2001) and “DESTINY” International Energy Forecast Software (Dallas, TX: Petroconsultants, 2001). **S&P:** Standard & Poor's Platt's, *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, February 2000). **PIRA:** PIRA Energy Group, *Retainer Client Seminar* (New York, NY, October 2000). **DBAB:** Deutsche Banc Alex.Brown, fax from Adam Sieminski (January 9, 2001).

8. Standard and Poor’s Platt’s, *World Energy Service: Latin American Outlook 1999* (Lexington, MA, 1999), p. 173.
9. J. Belcher, “PEMEX Attempts To Meet Refining Challenges as a State-Run Entity,” *Octane Week*, Vol. 15, No. 34 (August 21, 2000), pp. 6-8.
10. Standard & Poor’s, *World Energy Service: European Outlook, Volume II, 2000* (Lexington, MA, 2000), pp. 59, 85, 112, 159, and 183.
11. Standard & Poor’s, *World Energy Service: European Outlook, Volume II, 2000* (Lexington, MA, 2000), pp. 84-85.
12. Standard & Poor’s, *World Energy Service: European Outlook, Volume II, 2000* (Lexington, MA, 2000), p. 111.
13. “Offshore Prospects Delayed in Low Price Environment,” *Hart’s E&P*, Vol. 72, No. 1 (January 1999), p. 40.
14. DRI / McGraw-Hill, *Oil Market Outlook* (Lexington, MA, July 1995), Table 1, p. 10.
15. Energy Information Administration, *Oil Production Capacity Expansion Costs for the Persian Gulf*, DOE / EIA-TR / 0606 (Washington, DC, February 1996).

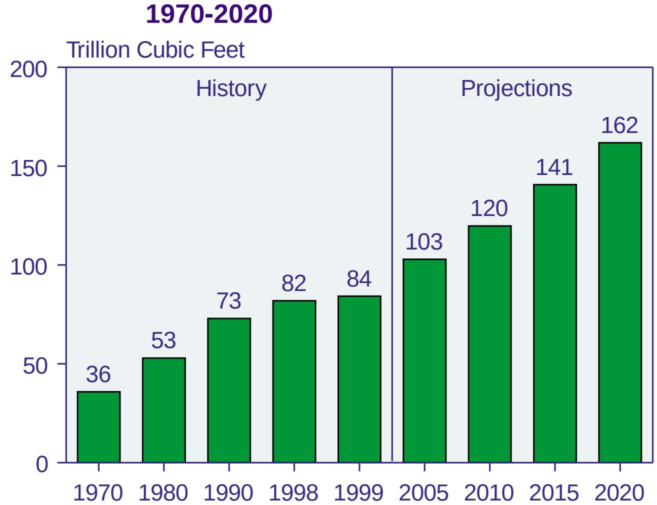
Natural Gas

Natural gas is the fastest growing primary energy source in the IEO2001 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 2001* (*IEO2001*) reference case. Gas use is projected to almost double, to 162 trillion cubic feet in 2020 from 84 trillion cubic feet in 1999 (Figure 38). With an average annual growth rate of 3.2 percent, the share of natural gas in total primary energy consumption is projected to grow to 28 percent from 23 percent. The largest increments in gas use are expected in Central and South America and in developing Asia, and the developing countries as a whole are expected to add a larger increment to gas use by 2020 than are the industrialized countries. Among the industrialized countries, the largest increases are expected for North America (mostly the United States) and Western Europe (Figure 39).

In the *IEO2001* reference case, the world share of gas use for electricity generation is projected to rise to 26 percent in 2020). Natural gas accounts for the largest projected increment in energy use for power generation, at 32 quadrillion British thermal units (Btu) between 1999 and 2020, as compared with an increment of 19 quadrillion Btu projected for coal. As a result, a growing interconnection between the gas and power industries is expected (see box on page 52).

Figure 38. World Natural Gas Consumption, 1970-2020



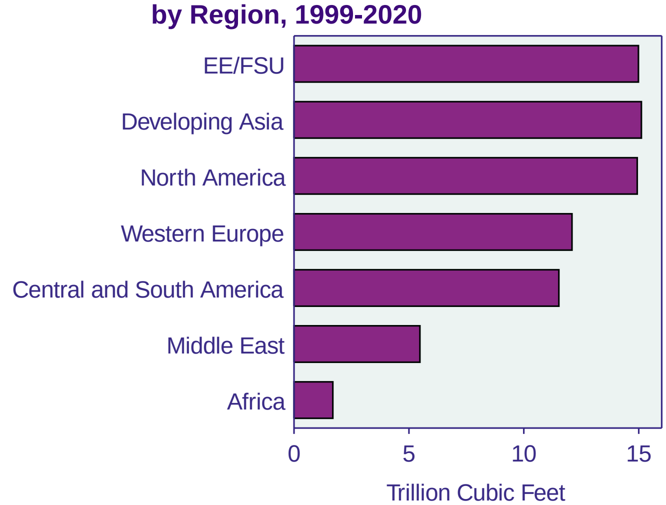
Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, World Energy Projection System (2001).

The projections for natural gas consumption in the industrialized countries show more rapid growth and a larger share of the total expected increase in energy consumption than are projected for any other energy fuel. Gas use is projected to grow by 2.4 percent per year in the industrialized countries (compared with 1.1 percent for oil) and to account for 49 percent of the projected increase in their total energy use. Natural gas is projected to provide 25 percent of all the energy used for electricity generation in the industrialized countries in 2020, up from 14 percent in 1999.

The *IEO2001* projections for the developing countries show similar trends for natural gas use, starting from a smaller share of total energy used in 1999 (16 percent for the developing countries, compared with the world average of 23 percent). In the reference case, natural gas consumption is projected to grow more rapidly than the use of any other fuel in the developing countries from 1999 to 2020, by an average 5.2 percent per year, compared with 4.9 percent per year for nuclear energy, 3.7 percent for oil, 3.1 percent for coal, and 2.8 percent for renewable energy (primarily hydropower).

Around the world, gas use is increasing for a variety of reasons, including price, environmental concerns, fuel

Figure 39. 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, January 2001). **2020:** EIA, World Energy Projection System (2001).

diversification and/or energy security issues, market deregulation (for both gas and electricity), and overall economic growth.[6] In many countries, governments hold equity in natural gas companies, and this can be used as a policy instrument. In Asia, examples include Kogas (Korea), Petronas (Malaysia), Pertamina (Indonesia), China National Petroleum Corporation, and Gas Authority of India Ltd. In the Middle East and Africa, examples include 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.

Barely 20 percent of the natural gas that the world consumed in 1999 was traded across international borders, as compared with 50 percent the oil consumed. Trade of both fuels grew steadily in the late 1990s, but natural gas is more complex to transport and generally requires larger investments. In addition, many gas resources are located far from demand centers.

Future world gas consumption will require bringing new gas resources to market. Currently, the economics of transporting natural gas to demand centers depends on the market price, and the pricing of natural gas is complicated by the fact that it is much less traded than oil. In Asia and Europe, for example, markets for liquefied natural gas (LNG) are strongly influenced by oil and oil product markets. As the use and trade of gas continue to grow, it is expected that pricing mechanisms for natural gas will continue to evolve, facilitating international trade.

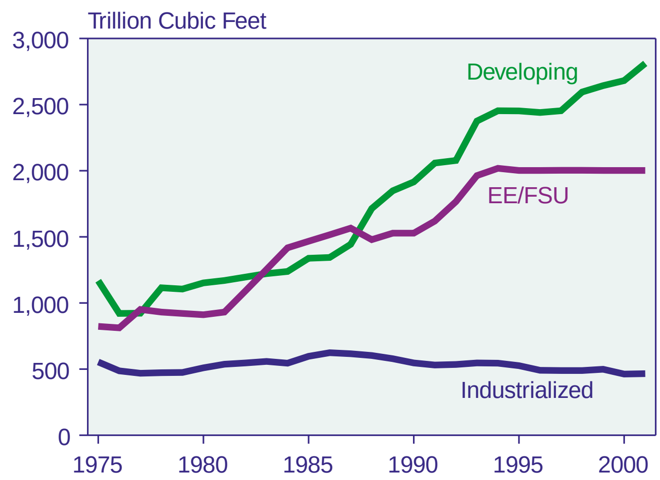
Reserves

Global natural gas reserves doubled over the past 20 years, outpacing growth in oil reserves over the same period. Gas reserve estimates have grown particularly rapidly in the former Soviet Union (FSU) and in developing countries in the Middle East, South and Central America, and the Asia Pacific region (Figure 40). The *Oil & Gas Journal* estimated proven world gas reserves as of January 1, 2001, at 5,278 trillion cubic feet, an increase of 132 trillion cubic feet over the 2000 estimate (see box on page 46).[7]

The largest increases in estimated reserves in 2000 were in the Middle East and in Central and South America. In the Middle East, where reported reserves grew by more than 100 trillion cubic feet, additions were concentrated in Saudi Arabia and Israel. In Central and South America, gas reserves reported by Bolivia grew fourfold, and reserve additions were also reported for Venezuela, Argentina, and Trinidad and Tobago. Other regions reported either very small changes in reserves or no change at all. New reserves in Norway played a large role in the small increase for Europe, and a small increase for developing Asia reflected reserve additions in Papua New Guinea.

World gas reserves are somewhat more widely distributed among regions than are oil reserves. For example, the Middle East holds 65 percent of global oil reserves but only 35 percent of gas reserves (Figure 41). Thus, some regions with limited oil reserves hold significant gas stocks. The FSU accounts for around 6 percent of world oil reserves but roughly 35 percent of proven gas reserves. Most of the gas (32 percent of world reserves) is located in Russia, which has the largest reserves in the world—more than double those in Iran, which has the second largest stocks. In the Middle East, Qatar, Iraq, Saudi Arabia, and the United Arab Emirates also have significant gas reserves (Table 16). Reserve-to-production (R/P) ratios exceed 100 years for the Middle East and are nearly as high for Africa (about 98 years) and the FSU (about 82 years). The R/P ratio for Central and South America is also high (about 66 years), as compared with only 10 years for North America and about 18 years for Europe. For the world as a whole, current average R/P ratios are 61.9 years for natural gas and 41 years for oil [***1***].

Figure 40. World Natural Gas Reserves by Region, 1975-2001

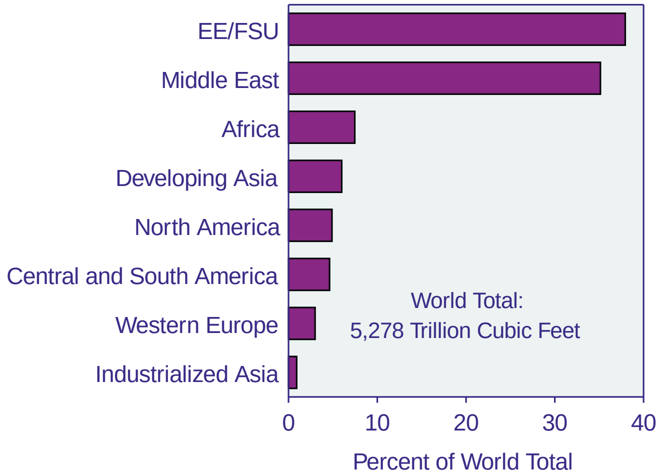


Sources: **1975-1993:** "Worldwide Oil and Gas at a Glance," *International Petroleum Encyclopedia* (Tulsa, OK: PennWell Publishing, various issues). **1994-2001:** *Oil & Gas Journal* (various issues).

[6]In some places, such as Japan, deregulation policies could lead to less gas use; in the United States, deregulation is expected to increase gas use.

[7]Proven 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 (see box on page 46 for discussion of reserves). Significant gas discoveries made during 2000 are not likely to be reflected in the reported reserves.

Figure 41. World Natural Gas Reserves by Region as of January 1, 2001



Source: "Worldwide Look at Reserves and Production," *Oil & Gas Journal*, Vol. 98, No. 51 (December 18, 2000), pp. 121-124.

Table 16. World Natural Gas Reserves by Country as of January 1, 2001

Country	Reserves (Trillion Cubic Feet)	Percent of World Total
World	**5,278**	**100.0**
Top 20 Countries	**4,678**	**88.6**
Russia	1,700	32.2
Iran	812	15.4
Qatar	394	7.5
Saudi Arabia	213	4.0
United Arab Emirates	212	4.0
United States	167	3.2
Algeria	160	3.0
Venezuela	147	2.8
Nigeria	124	2.3
Iraq	110	2.1
Turkmenistan	101	1.9
Malaysia	82	1.6
Indonesia	72	1.4
Uzbekistan	66	1.3
Kazakhstan	65	1.2
Canada	61	1.2
Netherlands	63	1.2
Kuwait	52	1.0
China	48	0.9
Mexico	30	0.6
Rest of World	**600**	**11.4**

Source: "Worldwide Look at Reserves and Production," *Oil & Gas Journal*, Vol. 98, No. 51 (December 18, 2000), pp. 121-124.

Regional Activity

North America

The countries of North America continue to move toward an integrated natural gas market. Cross-border natural gas pipeline capacity between the United States and its neighbors, Canada and Mexico, is increasing, export/import activity is growing, and prices in the three countries are converging. The most significant additions to cross-border capacity since 1998 have been between the United States and Canada, with the expansion in 1998 of the Northern Border system through Montana into the Midwest (650 million cubic feet per day); the December 2000 opening of the Alliance Pipeline through North Dakota into Chicago (1,325 million cubic feet per day); and the opening of the Maritimes and Northeast system on December 31, 1999 (400 million cubic feet per day). The Northern Border and Alliance projects provide access to Western Canadian natural gas, and the Maritimes and Northeast project transports supplies from Sable Island in the North Atlantic to New England markets. U.S. net imports from Canada in 1999 increased by 8.9 percent over 1998 levels, mainly because of the Northern Border expansion from Iowa to Illinois just south of Chicago.

Pipeline capacity between the United States and Mexico has increased by 70 percent since 1998, from 1,150 billion cubic feet per day to 1,970 billion cubic feet. The increase resulted from three projects: the September 1999 opening of the Tennessee Pipeline near Alamo, Texas (220 million cubic feet per day); the October 2000 opening of the Coral Energy pipeline between Kleburg County and Hidalgo County, Texas, to the border that will serve the state oil company, Pemex, at Arguelles, Mexico (300 million cubic feet per day); and the April 2000 opening of the Rosarito pipeline from San Diego County to Rosarito, Baja California (300 million cubic feet per day). The Tennessee and Coral Energy pipelines are bidirectional. (Although most capacity between the United States and Canada flows into the United States, approximately 75 percent of the capacity between the United States and Mexico is bidirectional.) A number of additional projects have been proposed and may proceed if the trend of increased trade with Mexico continues. Current plans include two El Paso Natural Gas projects, one that will add 130 million cubic feet per day of capacity at the Arizona/Mexico border and the other a project to increase compression on the Samalyuca pipeline, which will add 60 million cubic feet per day at the Texas/Mexico border.

Although North America accounted for 5.0 percent of the world's total natural gas proved reserves at the end of 1999, it accounted for 31.8 percent of the world's total production, most of which was consumed internally. The United States accounted for 23.2 percent of the world's total production, second only to Russia's 23.7 percent. Canada was the world's third largest natural gas producer, accounting for 7.0 percent of the total.

World Natural Gas Resources: A 30-Year USGS Perspective

The U.S. Geological Survey (USGS) periodically assesses the long-term production potential of worldwide petroleum resources (oil, natural gas, and natural gas liquids) resources. The most recent USGS estimates, released in the *World Petroleum Assessment 2000* (*WPA2000*),[a] are the culmination of a 5-year effort based on extensive geologic information from Petroconsultants, Inc.[b] and NRG Associates.[c] Previous analyses by the USGS[d] and the U.S. Minerals Management Service[e] were used for the purpose of including U.S. estimates in the world totals.

The *WPA2000* is the fifth in a series of assessments that began in 1981. Two aspects of the *WPA2000* analysis represent departures from the methodology used in previous assessments. First, the current assessment adopts a 30-year forecast period (1995-2025), whereas earlier USGS assessments assumed an unlimited forecast span. The use of a finite forecast span allows for a more detailed evaluation of petroleum-related activities whose availability during the forecast period is uncertain. For example, certain political (ecologically sensitive areas) or physical (extreme water depths) attributes might preclude some fields from being developed over the next 25 years.

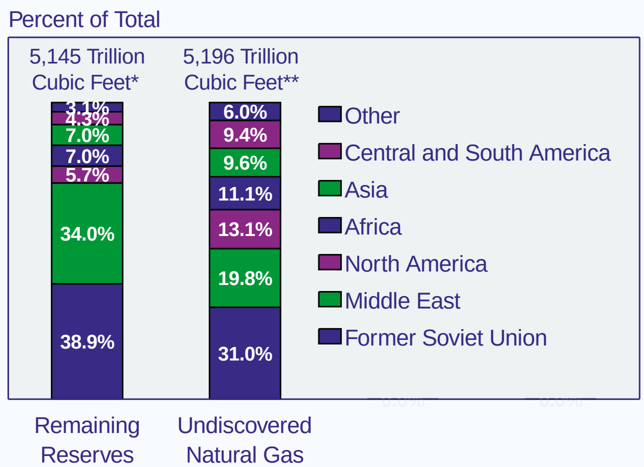
Second, the current assessment segregates future petroleum resources into two categories: undiscovered and reserve growth. Previous USGS assessments defined future petroleum only in terms of ultimately recoverable resources and did not separately address the concept of reserve growth. This concept refers to an increase in estimated field size due mainly to technological factors that enhance a field's recovery rate. As sophisticated technologies become more transferrable worldwide, reserve growth will become an increasingly important component of ultimate resource estimates. The methodologies employed in the *WPA2000* are considered important refinements to those used in previous assessments.

Highlights of the *WPA2000* projection for worldwide natural gas resources include:

- A significant volume of natural gas remains to be discovered. The mean estimate for worldwide undiscovered gas is 5,196 trillion cubic feet, or 886 billion barrels of oil equivalent. This mean estimate is more than double worldwide cumulative production but is less than the sum of remaining reserves and reserve growth estimates. About one-fourth of worldwide undiscovered gas resides in undiscovered oil fields.

- More than half of the mean undiscovered gas estimate is expected to come from the former Soviet Union, the Middle East, and North Africa. An additional 1,169 trillion cubic feet is expected to come from a combination of North, Central, and South America. The figure below shows the regional distribution of existing gas (remaining reserves) and potential gas (undiscovered).

World Natural Gas Resources by Region



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

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

- 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. 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.

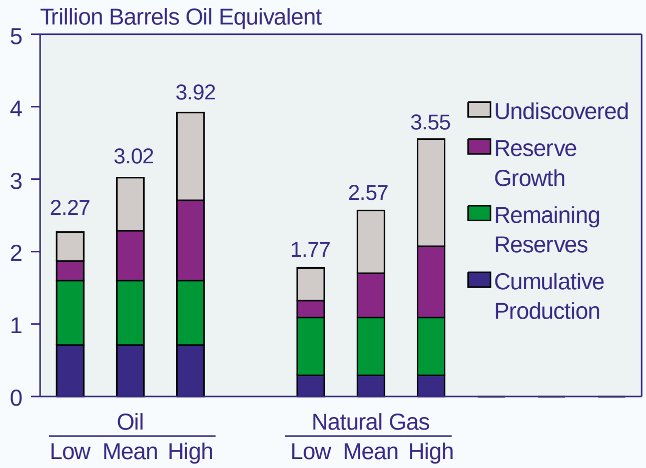
(continued on page 47)

[a]U.S. Geological Survey, *World Petroleum Assessment 2000*, web site http://greenwood.cr.usgs.gov/energy/WorlEnergy/DDS-60.
[b]Petroconsultants, Inc., *Petroleum Exploration and Production Database* (Houston, TX, 1996).
[c]NRG Associates, Inc., *The Significant Oil and Gas Pools of Canada Data Base* (Colorado Springs, CO, 1995).
[d]D.L. Gautier et al., *National Assessment of United States Oil and Gas Resources: Results, Methodology, and Supporting Data,* U.S. Geological Survey Data Series DDS-30, Release 2 (Denver, CO, 2000).
[e]U.S. Department of Interior, Minerals Management Service, *An Assessment of the Undiscovered Hydrocarbon Potential of the Nation's Outer Continental Shelf,* OCS Report MMS 96-0034 (Washington, DC, 1996).

World Natural Gas Resources: A 30-Year USGS Perspective (Continued)

Many energy analysts are more familiar with worldwide statistics for oil than they are with those for natural gas. For comparison, the USGS gas estimates can be expressed in terms of equivalent volumes of conventional oil. The figure below shows world oil and gas estimates out to 2025 in terms of trillion barrels of oil equivalent, including mean estimates as well as high and low estimates to indicate a range of uncertainty for reserve growth and undiscovered resources. Cumulative production and remaining reserves are also included.

World Oil and Gas Resources, 1995-2025



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

The following relationships between oil and gas resources are derived from the USGS mean estimates:

- Almost one-quarter of estimated worldwide oil resources have already been produced, compared with only slightly more than 10 percent of worldwide gas resources.
- The amount of oil expected to be either discovered or added to reserves as a result of enhanced recovery is approximately equal to the amount of gas expected to be discovered or added to reserves. For both oil and gas, the bulk of the resource that has yet to be produced resides in fields that have already been discovered.
- On an energy equivalent basis, world oil consumption over the next 25 years is expected to be almost double world consumption of natural gas.
- Whereas the estimates of undiscovered oil volumes in *WPA2000* are 20 percent greater than those in the previous (1994) USGS assessment, the estimates of undiscovered gas volumes are 14 percent smaller as a result of reduced estimates for the former Soviet Union, China, and Canada.

While the analytical rigor and information depth of the *WPA2000* are impressive, it is important to recognize that all long-term assessments are imperfect. The USGS acknowledges that petroleum economics and technological improvements are critical unknowns whose evolution over time will have a profound impact on the world's petroleum resource potential. In addition, the USGS assessments are limited to conventional resources only, excluding trillions of barrels of oil equivalent from the resource base. Estimates of worldwide heavy oil and tar sands exceed 3.2 trillion barrels, with Canada and Venezuela accounting for most of the deposits.[f] The range of estimates for worldwide shale oil resources is staggering, running from a conservative 12 trillion barrels to a considerably more optimistic 2.1 quadrillion barrels.[g] Coalbed methane deposits are estimated to hold more than 1 quadrillion cubic feet of gas, with most of the resource located in the United States, Canada, and China.[h]

The USGS petroleum assessments will continue to provide an important foundation for additional geologic, economic, geopolitical, and environmental studies. With many of the world's economies intrinsically linked to energy resource availability, such studies also provide essential long-term strategic guidance.

[f]About Oil / Gas, *Heavy Oil and Tar Sands–A Present and Future Resource*, on-line version web site http://petroleum.about.com/industry/petroleum/library/weekly/aa032999.html (March 29, 1999).

[g]W. Youngquist, *Shale Oil—The Elusive Energy*, Newsletter No. 98/4 (Golden CO: M. King Hubbert Center for Petroleum Supply Studies, Fourth Quarter 1998).

[h]D.D. Rice, *Coalbed Methane—An Untapped Energy Resource and An Environmental Concern*, U.S. Geological Survey Fact Sheet FS-019-97 (Denver, CO, 1997).

Mexico produced only slightly more gas than it consumed in 1999, whereas Canada produced more than twice as much as it consumed [*2*]. Almost all the excess production in both Canada and Mexico was exported to the United States to fill the widening gap between U.S. production and consumption. U.S. exports to Canada from the United States were negligible, but exports to Mexico—primarily to satisfy demand in areas where Mexico did not have the infrastructure to get its own domestic supplies to market—exceeded imports by 12.5 percent. In 1999, U.S. net imports of natural gas represented 15.8 percent of consumption, and in EIA's *Annual Energy Outlook 2001* (*AEO2001*), imports are projected to make up 16.7 percent of U.S. consumption in 2020.

Canada, which supplied 95 percent of U.S. natural gas imports in 1999, is expected to continue to be the primary source of U.S. imports.

A growing source of U.S. imports is liquefied natural gas (LNG). Four LNG receiving terminals exist in the United States, but two (Cove Point, Maryland, and Elba Island, Georgia) have been mothballed for many years. Higher natural gas prices, reductions in the costs of producing and transporting LNG, and the development of new sources have caused renewed interest in LNG, and there are plans to reopen both the Cove Point and Elba Island facilities by 2002 [***3***]. In conjunction with the reopening, Willams, the owner of the Cove Point facility, has announced plans to add a fifth storage tank to the four existing tanks. When it is open, Cove Point will be the largest of the four U.S. terminals.

Algeria was once the only source of LNG supply for the United States, but Trinidad and Tobago has now become the primary source of supply, with cargos coming also from Qatar, Nigeria, Australia, Oman, and the United Arab Emirates. In addition, spot market sales are now becoming routine. For the first 9 months of 2000, 36 out of 74 cargoes received were spot sales, with long-term contract sales only with Trinidad and Tobago and Algeria.

All indications are that LNG imports will grow in the future. The aggregate existing sustainable capacity of the four U.S. facilities is 840 billion cubic feet per year, and their capacity could be expanded. CMS Trunkline LNG Company, owner of the Lake Charles, Louisiana, facility, is considering expanding the facility to add 110 billion cubic feet per year of deliverability. CMS is currently conducting an open season through February 15, 2001, to assess interest in long-term contracts starting in early 2002, and will base its decision on the outcome. Although LNG is not expected to become a major source of U.S. gas supply, it does play an important role in regional markets, including New England. In the *AEO2001*, gross LNG imports are projected to grow from 90 billion cubic feet in 1998 to 810 billion cubic feet in 2020 [***4***].

Although Mexico has the resource base needed to become a source of increasing future imports for the United States, the country's own consumption is rapidly increasing, and its indigenous production is not expected to increase sufficiently to meet the growing demand. Pemex is anticipating demand growth of approximately 9 percent per year over the next 10 years. To meet rising demand, Pemex is actively promoting the expansion of cross-border capacity to allow increased imports. Over the longer term, Pemex hopes to develop more of its own resources, both to reduce Mexico's dependence on imports and to increase its exports to the United States. It is unclear, however, whether Mexico will be able to increase production significantly, and it is likely that Mexico will remain a net importer of natural gas for the foreseeable future.

The *IEO2001* reference case projects average annual growth in natural gas consumption in North America between 1999 and 2020 of 2.2 percent and annual growth rates of 1.5 percent in Canada, 2.3 percent in the United States, and 2.2 percent in Mexico. The driving force behind the growth in all three countries is the increased consumption of natural gas for electric power generation. In the United States, natural gas consumption for electricity generation (excluding cogenerators) is projected in the *AEO2001* to triple from 3.8 trillion cubic feet in 1999 to 11.3 trillion cubic feet in 2020.

Partly as a result of increasing demand for natural gas with new gas-fired power plants coming on line, and partly due to the decline in drilling that resulted from low natural gas prices over the past few years, natural gas prices rose sharply in 2000 in all of North America, with prices at the U.S. Henry Hub more than quadrupling from those seen just a year earlier. Consumers have seen, and will most likely continue to see, substantial increases in natural gas costs. In California, where insufficient pipeline capacity both at the border and within the State has severely limited the availability of supply to meet rapidly growing demand, border prices that exceed the New York Mercantile Exchange (NYMEX) price more than sixfold have been seen [***5***].

California's electricity transmission has recently been plagued with rolling blackouts in portions of the State (see box on page 126), and electric utilities have been encouraging consumers to limit usage in order to prevent repeat occurrences. The prices have taken their toll on industry both in California and in other parts of the country. There have been cutbacks and closures at aluminum smelting plants in the Pacific Northwest, and the ammonia, urea, and methanol industries are also cutting back. Several manufacturers that have hedged their gas supplies have found that it is more profitable to either shut down or cut back and sell the gas at considerable profit margins. Examples are Terra Nitrogen, which shut down its Arkansas fertilizer plant and cut back its Oklahoma plant, and Mississippi Chemical, which halted fertilizer production. Both companies are selling their natural gas futures contracts. High gas prices have precipitated high electricity prices, causing companies such as Kaiser Aluminum and Chemical to close plants in Mead and Tacoma, Washington and Georgia Pacific to close a paper mill in Bellingham, Washington [***6***].

The high prices that have caused problems for natural gas consumers have also spurred considerable interest and investment in exploration and development. EIA's February 2001 *Short-Term Energy Outlook* projects that domestic natural gas production in 2001 will exceed the

2000 level by about 1 trillion cubic feet (5.4 percent). The U.S. natural gas rig count grew from 371 in April 1999 to 840 as of November 10, 2000. Thus, although wellhead prices are projected to rise from an estimated $3.73 (nominal dollars) per thousand cubic feet in 2000 to $4.95 in 2001, they are expected to retreat in 2002 to $4.52.

Canada

Rig counts in Canada have also grown, and preliminary estimates indicate that more than 7,000 new gas wells were drilled there in 2000. Considerable investment has already been made in expansions of export capacity from Canada to the United States. For example, the 1,875-mile Alliance Pipeline that recently began operation required an investment of $2.5 billion. In addition, the *AEO2001* preliminary estimates indicate that investment on interstate pipeline expansion within the United States in 1999 exceeded $2 billion and that investment in 2000 will reach approximately the same level.

Both the United States and Canada are seeing a revival of interest in an Arctic pipeline, which was considered and subsequently shelved in the 1970s as uneconomical. Combined Alaskan and Canadian proved reserves in the Alaska North Slope, McKenzie Delta, and the Beaufort Sea are approximately 40 trillion cubic feet, with the potential for far more. The Alaska, Yukon, and Northwest Territory governments all support different routes, however, and it is estimated that the earliest completion date for any of the proposed routes would be 2007 [***7***].

High gas prices have also caused industry to be hard hit in Canada and Mexico. The impact has been especially severe in Western Canada—where abundant supplies priced considerably below U.S. levels had long been available—because excess gas production could not be moved to markets in other regions. With recent increases in pipeline capacity to move Western Canadian gas to the United States, the price differential from U.S. gas has narrowed to the point that many consider them to be on a par. Between 1998 and 1999 alone, the differential between NYMEX-based gas prices and the Canadian benchmark AECO-C prices decreased from an average of $1.14 per thousand cubic feet to $0.42 [***8***].

The increase in natural gas prices for many Canadian consumers has been more pronounced than the increase to U.S. consumers. A number of Western Canadian companies, with plants close to sources of natural gas that had been available at prices considerably below U.S. prices before the opening of new pipeline capacity between Canada and the United States, have closed plants and rethought spending plans. Prominent producers of specialty chemicals and fertilizers made from natural gas have been forced to shut plants in Western Canada and increase production at overseas plants where gas is relatively cheap. Methanex Corporation, the world's largest producer of methanol (a natural gas derivative used to make industrial chemicals), mothballed its original plant in British Columbia in July 2000, and Sherritt International Corporation suspended fertilizer production at its Fort Saskatchewan facility in October 2000 [***9***].

Mexico

In Mexico, where the price of natural gas is set by Pemex based on U.S. benchmarks (specifically, Houston ship channel prices plus transport costs to Mexico), industrial consumers are facing similar problems. On September 21, 2000, Mexico's second largest steel manufacturer, Hylsa, announced the partial suspension of operations at three iron mines and their related ore-processing plants, stating that the high gas prices had made them uneconomical [***10***]. Facing additional layoffs, production cutbacks, and possible closings, many industrialists, particularly in the glass, mining, and steel industries in northern Mexico's Monterrey, have been pressuring Pemex to revise the pricing mechanism or provide some other form of relief [***11***]. While Pemex did announce plans to develop resources more aggressively and increase cross-border pipeline capacity, the only immediate relief it has offered major consumers has been a willingness to finance a portion of their natural gas costs.

Mexico's Energy Regulatory Commission (CRE) took steps in August to ameliorate the situation in the longer term by announcing plans to begin a restructuring of the gas industry in order to reduce the effects of price volatility. The initiative, which will allow private investors to participate in the development of transportation, storage, and distribution infrastructure, has resulted in commitments of $2.2 billion to build about 24,000 miles of pipeline [***12***]. On October 4, 2000, the CRE issued a call for a public consultation to solicit proposals on how to open the market to more private sector suppliers [***13***]. Proposals relating to the public consultation were due in November, and they are scheduled to be published in January 2001, followed by an issuance in March of the CRE's proposals based on the suggestions.

The CRE also implemented a month-long program during August 2000 in which industrial customers who could show proof of either having purchased futures contracts or put some other form of hedging instrument in place were offered a 25-percent discount on natural gas prices. Approximately 355 companies, representing 85 percent of Mexico's natural gas consumption, took advantage of the 25-percent discount offer [***14***]. The primary purpose of the offer was to promote the use of hedging instruments, and the CRE president at that time, Hector Olea, initially indicated that it would not be repeated and other subsidies would not be introduced.

In subsequent discussions, Olea did not rule out future subsidies that might be implemented by the incoming Vicente Fox administration after Fox took office on December 1, 2000. Olea, at the end of his 5-year term as chairman, resigned in November. While the incoming administration favors restructuring Mexico's energy markets, Fox may have difficulty implementing any sweeping reform, because his party lacks a majority in Congress.

President Fox would in particular like to encourage an opening of the upstream portion of the market to competition so that Mexico's natural gas resources could be developed at a more rapid pace. The distribution segment of the industry has been opened to private investment since 1995, but Pemex by constitutional mandate still controls exploration and production. Mexico remains the only North American country in which a segment of the natural gas market is directly controlled by the government.

Pemex has announced plans to develop gas reserves in a number of areas, including the northern Burgos basin, in an effort to increase gas production and reduce imports to zero by 2004. The Pemex program calls for $12 billion in spending, according to a September 26, 2000, statement by Energy Undersecretary Mauricio Toussaint [***15***]. Heavy industry has still been clamoring for a loosening of Pemex control, however, indicating that the current plans will not develop resources rapidly enough to meet rising demand or to alleviate the current short-term situation. If the government is slow to act, Mexico could be facing serious obstacles to meeting internal demand at acceptable prices.

U.S. President George Bush during his election campaign expressed concern over the future of Mexico's gas market and called for a "hemispheric energy policy where Canada and Mexico and the United States come together." He indicated that he and President Fox had discussed expediting gas exploration in Mexico for transport to the United States [***16***]. In September, a delegation from the Texas Railroad Commission met with CRE members to discuss ways the agencies could cooperate to encourage the construction of more cross-border capacity between South Texas and northern Mexico [***17***].

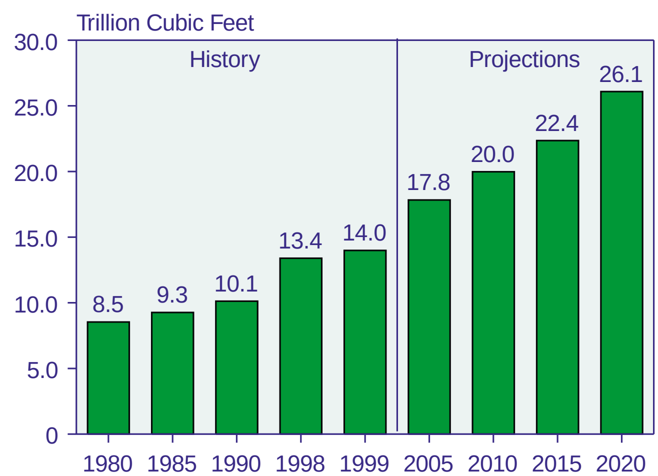
Western Europe

Western Europe's natural gas reserves are limited (less than 5 percent of global resources) and are concentrated along with gas production in the Netherlands, Norway, and the United Kingdom. Nearly one-third of the region's gas demand is met by pipeline imports from the former Soviet Union and Algeria and LNG from North Africa. Recent demand increases reflect rising gas use for power generation as well as in the industrial sector. *IEO2001* projects that the demand for natural gas in Western Europe will grow at an average annual rate of 3.0 percent from 1999 to 2020, reaching 26.1 trillion cubic feet in 2020 (Figure 42).

The year 2000 was important for natural gas in Western Europe because the European Union (EU) had set a deadline of August 10, 2000, for members to have an arrangement in place for third-party access to gas infrastructure (see box on page 52). The European Parliament and Council Directive 98/30/EC of June 22, 1998, set common rules for the EU's internal market in natural gas. By August 10, 2000, all gas-fired power generators and customers using more than 883 million cubic feet of gas per year were to be "eligible" to choose a gas supplier. The EU distinguishes between "eligibility," or the legal right to choose a supplier, and truly competitive markets in which customers have a real choice. Under the directive, further deadlines expand eligibility, first to customers of at least 530 million cubic feet per year by 2003 and then to those using at least 177 million cubic feet per year by 2008. The directive also gives the emerging markets in Portugal and Greece more leeway [***18***].

Not all member countries met the August 10, 2000, deadline because of the many issues and politics of the EU and the gas industry there. Spain and Belgium are partly compliant, with some third-party access to gas infrastructure, and have plans to become completely compliant over the next 10 or so years. The United Kingdom, on the other hand, is already 100 percent compliant with the EU directive. France, Portugal, and Luxembourg were sent warning letters about their failure to comply by the EU Energy Commissioner, Loyola De Palacio, and have also received formal "infringement notice"

Figure 42. Natural Gas Consumption in 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, January 2001). **Projections:** EIA, World Energy Projection System (2001).

from the European Commission, which could lead in theory to legal action by the Court of Justice. The EU has also scrutinized and questioned German compliance, but no formal action has been taken. Germany has struggled with setting fees to exit points in its transportation system, which involves more than 700 operators.

The ultimate impact of the EU directive on creating a "single European gas market" is uncertain, but the EU has not ruled out taking further measures, and EU energy ministers have discussed tougher draft amendments [***19***]. Other catalysts for change in the European gas market may also come from growing trading opportunities (such as via the Interconnector pipeline between the United Kingdom and continental Europe) or from forces of abundant supply.

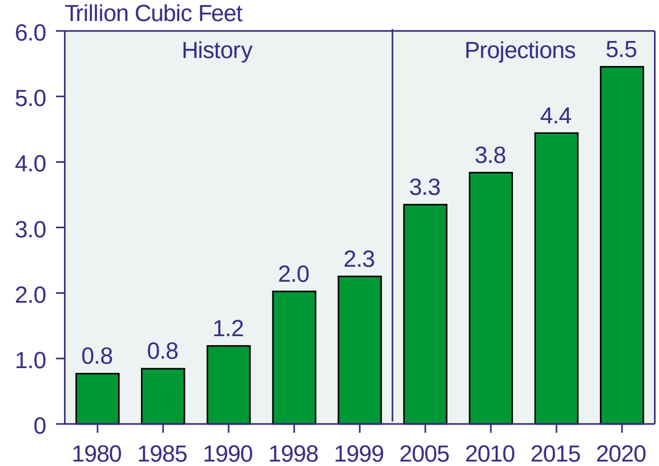
In the *IEO2001* outlook, the projected 3.0-percent annual growth rate for natural gas consumption in Western Europe is not particularly rapid in comparison with other regions. However, excluding five of the largest countries in the region (France, Germany, Italy, the Netherlands, and the United Kingdom), gas use in the other countries of Western Europe is expected to grow by 4.3 percent per year between 1999 and 2020 (Figure 43). Rapid expansion in gas use is readily apparent in Spain, Italy, and Portugal, where there were numerous important gas industry developments during 2000, and the investment plans of some industry players may be accelerated or become more aggressive as governments announce timetables for deregulation [***20***].

In Spain, plans to expand LNG imports continue with two new receiving terminal projects. One terminal is scheduled to begin operations in 2003 in the northern Basque region in the newly expanded port of Bilbao. The project involves the company Bahia de Bizkaia Gas (BBG), owned by BP Amoco, Iberdrola, Repsol YPF, and Ente Vasco de la Energia (the Basque energy authority). Gas imports would initially be delivered to an 800-megawatt power plant in addition to Repsol and the Basque gas distributor (Gas de Euskadi). A turnkey contract for the terminal was awarded in summer 2000 to a consortium led by SN Technigaz [***21***].

Another Spanish LNG terminal project involves Spain's third largest power company, Union Fenosa, which has signed a deal with Egyptian General Petroleum Corporation (EGPC) for LNG supply. Providing Fenosa with its own gas source from 2004, the agreement calls for Fenosa to invest $1 billion in a liquefaction terminal, shipping arrangements, and participation in regasification. The project would help Fenosa compete with Repsol-Gas Natural as a supplier in the newly opening market [***22***].

During the spring of 2000, Union Fenosa and a Spanish subsidiary of U.S. energy company Enron were awarded gas supply licenses for the Spanish market. More than

Figure 43. Natural Gas Consumption in Other Western Europe, 1980-2020



Note: Other Western Europe includes all the countries of Western Europe except France, Germany, Italy, the Netherlands, and the United Kingdom.

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, January 2001). **Projections:** EIA, World Energy Projection System (2001).

eight other licenses for capacity in the pipelines of Gas Natural were awarded in the preceding months [***23***]. Gas Natural also moved up investment plans for extending its pipeline network following a government decision to take only 10 years (not 14) for the transition to an open market [***24***].

The projects planned and the jockeying of various companies to compete in Spain reflects the type of battles or issues being raised in parts of Europe as the EU's plans for electricity and gas industry deregulation move forward. Repsol YPF, Spain's premier oil and gas group, has sought entrance to the electricity market, but electric utilities initially fought the move, arguing that it would not be reciprocal (providing unfair advantage to Repsol) until the gas market also opened and offered similar access [***25***].

Elsewhere in southern Europe, Portugal's state gas distribution company, Transgas, began receiving Nigerian LNG via the regasification terminal at Huelva in southern Spain. Portugal is also constructing its first LNG terminal at Sines (55 miles south of Lisbon) in conjunction with a 1-gigawatt combined-cycle gas turbine power plant. Transgas Atlantico (TA), a joint venture between Transgas and state gas company Gas de Portugal, would like LNG to meet half of the country's growing gas needs by 2010 [***26***]. Under the EU gas directive, Portugal is considered an emerging natural gas market (having only begun using gas in 1998) and is not required to open its domestic gas market to full competition until 2008.

Natural Gas and Electricity in Western Europe

The natural gas and electric power industries in Europe are becoming increasingly interconnected. Both industries have been set on a course of change by parallel directives from the European Union (EU) calling for deregulation. Growing availability of natural gas supplies, efforts to introduce greater competition in energy supply, and improvements in natural gas turbine technology are driving the convergence of natural gas and electricity in Western Europe.

Until the early 1970s, gas supplies in Europe came predominantly from sources within the region. Around that time, however, supplies started to come from other sources as well, with the beginning of liquefied natural gas (LNG) deliveries from North Africa (Algeria and Libya) and pipeline gas from the Soviet Union. Also at that time, the United Kingdom (UK) and later Norway began to develop North Sea hydrocarbon resources. Gas demand, along with economic growth, waned in the early 1980s just when earlier investments in gas transportation infrastructure were adding capacity—particularly the Trans-Mediterranean pipeline (from Algeria to Italy), pipelines from Norway, and additional pipeline capacity from the Soviet Union. As gas demand grew stronger in the late 1980s and 1990s, the supply mix continued to reflect growing pipeline imports with a smaller share of imported LNG.[a] Growth in the more separated UK gas market was especially strong, supplied by rising domestic from the North Sea and eventually imports from Norway. Only with the 1998 commissioning of the UK-Belgium Interconnector pipeline has a more integrated, cross-channel European gas market become possible.

Currently, pipelines transport more than three-quarters of the natural gas imported by EU members. About 40 percent of those pipeline imports arrive from the Russian Federation and 15 percent from North Africa (predominantly Algeria).[b] Intra-EU trade, primarily in gas from the Netherlands, accounts for just about 20 percent of the pipeline imports; however, when exports from Norway are included, the countries of Western Europe obtain nearly 45 percent of their pipeline gas imports from other countries in the region.

Gas fields in the Netherlands are beginning to near depletion, which will constrain future exports. Norwegian gas discoveries have also dropped off, limiting current export possibilities to known resources (although the region is believed to still have gas potential, particularly in the offshore Norwegian Sea).[c] Thus, future incremental gas supplies are expected to arrive primarily from North Africa, the Middle East, and Russia.

As in the United States, energy policies have had an important effect on the availability of natural gas in Western Europe and its development as a fuel for electricity generation. In the 1970s, gas availability issues led to intervention in the industry by the European Community (EC, predecessor to the EU). In 1975, a perceived scarcity of gas resources led to an EC directive restricting the use of gas in power plants, which eventually was revoked in the early 1990s, when perceptions about the availability of gas resources and the competitiveness of gas turbine technologies had changed.[d] In contrast, the European Parliament and *(continued on page 53)*

[a]J. Estrada, H.O. Bergesen, A. Moe, and A.K. Sydnes, *Natural Gas in Europe: Markets, Organisation and Politics* (New York, NY: Pinter Publishers, 1988).

[b]BP Energy, *World Energy Statistics 2000*, web site www.bp.com.

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

[d]P. Soderholm, "Fuel for Thought: European Energy Market Restructuring and the Future of Power Generation Gas Use," *International Journal of Global Energy Issues* (forthcoming).

In Italy, projects, plans, and proposals for new LNG terminals are also linked with deregulation. Italy now has one LNG receiving terminal in operation. Edison/Exxon Mobil's plan for a terminal in the Adriatic Sea around the Po River delta (offshore Rovigo) received several first-stage approvals in 1999, and in early 2000 the Italian environment ministry approved the environmental impact study. The project is targeted for completion in 2003 [***27***]. Rivaling the Edison/ExxonMobil plans is a British Gas (BG) proposal to build a terminal in the southern city of Brindisi, for which there is already local clearance [***28***]. A major potential customer could be Enel, the state power company, which seeks to challenge the state gas player Snam as the gas market opens.

Snam, which is owned by Italy's state gas company Eni, controls 90 percent of the country's gas imports and 85 percent of its gas transport. Legislation to open the gas market was passed by the Italian senate in early summer 2000. Eni will not have to relinquish its gas transport network, but its share of gas imports will be capped at 75 percent and its share of gas sales limited to 50 percent of the market. This type or level of deregulation faces less opposition in Italy's high-growth gas market, because it is unlikely that Eni will have to cut or limit gas sales under the market share limits. In addition, Eni plans to generate power with some of its gas, which would then be counted as "self consumption" rather than sales of natural gas [***29***].

Natural Gas and Electricity in Western Europe (Continued)

Council Directive of June 22, 1998 (with an implementation deadline of August 10, 2000) was not about safeguarding supplies, but about promoting market-based development of the gas industry.

The 1998 gas directive—part of a regulatory trend worldwide in which (among other changes) both gas and power transmission systems are being made available to multiple users—seeks to end monopoly control of national gas transmission systems, which were once viewed as natural monopolies. Not all EU member countries have met the deadline for implementing the directive, however, and its effectiveness has been limited as a result. EU officials are continuing to focus on compliance while drafting further guidelines in case they are needed to promote an EU-wide gas market.

The increasing use of gas for power generation in Western Europe has played a central role in prompting the dual EU directives to alter gas and power market regulations. In turn, the current regulatory changes are having an important effect on corporate strategies and structures. European gas transmission companies, which increasingly must allow third-party access to their pipelines, are now seeking to move into both upstream and downstream businesses, expanding their profit base beyond the deregulating gas transmission market. Gas de France, for example, has bought offshore Dutch production assets from TransCanada. Some companies may have sought growth in order to compete more internationally. Others may have sought to protect their domestic markets from foreign investors.[e] Some of the mergers have involved corporations that hold extensive assets in both the gas and power industries, such as the combining of Germany's Veba and Viag to become E.ON. If the current trends in gas-fired generating technology, improving access to natural gas supplies, and EU regulation continue, further interconnection of the natural gas and electricity industries in Western Europe can be expected.

[e]P. Carpentier and A. Tagheghi, "Commercial Opportunities in European Gas Markets," in *World Power 2000* (London, UK: Isherwood Production Ltd., 2000).

In France, although the government has been slow to enact legislation complying with the EU gas directive, the state company Gaz de France volunteered to comply and undertook reorganization to facilitate its compliance. Access to the French gas infrastructure could be tested, however, by four big industrial gas users (Pechiney, Rhodia, St. Gobain, and Solvay) that have announced a tender to buy gas. The four companies account for about 4 percent of France's gas consumption [***30***].

Eastern Europe and the Former Soviet Union

At the end of 1999, natural gas deposits in the former Soviet Union (FSU) accounted for 2003 trillion cubic feet, or 38.7 percent of the world's proved reserves. While Russia continued to lead all other countries in total reserves, with 1,700 trillion cubic feet of proved reserves, or 32.2 percent of the world's total, Turkmenistan, Uzbekistan, and Kazakhstan each accounted for between 1 and 2 percent of the total.

Russia is both the world's largest natural gas producer and its largest exporter, with all the country's excess production going to exports. Russia far surpassed all other countries in gas production in 1999, providing 23.7 percent of the world's total supply, only slightly ahead of the U.S. share of 23.2 percent. Russia's 1999 gas production varied only slightly from 1998, at 19.5 trillion cubic feet. Russia provides Turkey with more than 75 percent of the gas it consumes and the EU with almost one-third of the gas consumed by its member countries. Major EU consumers of Russian gas are Germany, Italy, and France, each of which imported more than 400 billion cubic feet in 1999. Other major importers of Russian gas were the Czech Republic, Hungary, Slovakia, and Poland, each receiving more than 250 billion cubic feet. Most EE/FSU countries depend almost solely on Russia for their natural gas supplies.

Although neither Russia's natural gas production nor its consumption increased in 1999, largely because of its internal economic problems, production increases occurred throughout the remainder of the FSU, accompanied by increased consumption in all the major gas-consuming countries of the FSU. The major producing countries, in order of amount produced in 1999, were Uzbekistan, Turkmenistan, Ukraine, Kazakhstan, and Azerbaijan. Production from other FSU countries was negligible. Of particular note were production increases of 71.4 percent in Turkmenistan and 20.7 percent in Kazakhstan.

Outside Russia, Turkmenistan is the only significant exporter of natural gas in the EE/FSU, producing approximately 70 percent more gas than it consumed in 1999. Most of the excess production was exported to other EE/FSU countries, and about one-third went to Iran. Turkmenistan's sizable increase in production in 1999 resulted mainly from a resumption of exports to Ukraine, which Turkmenistan had cut off in 1997 and 1998 in response to Ukraine's nonpayment for previous deliveries.

Gas markets in the EE/FSU region 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. Nevertheless, the *IEO2001* reference case projects significant future growth in the region's natural gas consumption. Consumption in the EE/FSU as a whole is projected to grow at an average annual rate of 2.5 percent per year between 1999 and 2020. Consumption in the FSU is projected to grow at a rate of 1.8 percent a year, with slower growth in the early years of the forecast. The projected increase in Eastern Europe is considerably higher, at an overall rate of 5.9 percent per year. FSU consumption is projected to grow from 20.1 trillion cubic feet to 29.5 trillion, and EE consumption is projected to more than triple, from 2.4 trillion cubic feet in 1999 to 8.0 trillion in 2020.

Between 1997 and 1999, consumption declines in Eastern Europe outweighed increases, with consumption in Bulgaria, Romania, and Poland declining by 34 percent, 25 percent, and 5 percent, respectively, over the 2-year period. Countries posting gains included the Czech Republic and Hungary, but all the gains were modest (less than 2.0 percent).

Along with posting the highest gains in gas production among the FSU countries, Turkmenistan showed the highest consumption increase from 1997 to 1999, at 27 percent. Ukraine consumed more than 4 times what it produced and was thus, like the nonproducing countries, heavily dependent on Russian supplies. The other producing countries produced approximately what they consumed, and any dependence on imports in those countries resulted from a lack of infrastructure linking their producing areas with their demand centers [***31***]. The highest level of consumption in a nonproducing FSU country in 1999 was in Belarus.

Although Russia's gas production remained steady in 1999 and its reserves are plentiful, there is considerable talk of an impending gas shortfall. Russia has been forced to tap into its reserves, and its major active natural gas fields have been depleted by more than one-third, to the point of declining output. Gazprom does not have the capital needed to either develop new fields or pursue the upgrades desperately needed in the domestic gas industry, and government policy that holds down domestic gas prices and prevents independent producers from exporting gas discourages growth in production [***32***]. According to Gazprom's own figures, the country's natural gas shortfall will reach 388 billion cubic feet in 2000, 1,300 billion cubic feet in 2001, and 2,400 billion cubic feet in 2002. Russia's Deputy Energy Minister Valery Garipov has indicated that production could drop by almost 10 percent within the next 3 to 5 years. The situation has caused Gazprom to announce drastic cuts in gas sales to domestic power plants (the Russian Unified Power System) in 2001, citing its need to first honor agreements with foreign purchasers.

So far, Russia has not breached any of its supply contracts with its European buyers, but it has recently been unable to meet contractual obligations to supply gas to Azerbaijan. Deliveries to Azerbaijan were stopped at the beginning of the 2000/2001 heating season, forcing power plants supplying heat to operate at less than full capacity. As a result, Azerbaijan has announced plans to negotiate with Iran for future gas supplies [***33***]. Turkey, a major consumer of natural gas, despite its voiced concerns about too much dependence on Russia, seems to be increasing its dependence. At risk of a power shortage, Turkey has negotiated an increase of 15 to 20 percent in imports from Russia beginning in November 2000. The Blue Stream pipeline project, which will move natural gas under the Black Sea to Turkey, currently is scheduled for completion in the fall of 2001. With the pipeline in operation, Turkey will receive 60 percent of its natural gas imports from Russia [***34***].

Because the Russian government has mandated artificially low domestic prices for natural gas, Gazprom must cover its domestic losses with profits from the sale of gas at considerably higher prices in foreign markets [***35***]. Gazprom has indicated that domestic gas prices might have to double in order for Russian gas producers to stop losing money, and that increases of at least 50 percent would be needed to attract needed investment [***36***]. Russian president Vladimir Putin has indicated a desire to reform Gazprom (which is partially owned by the government). His success could allay many of the fears that currently keep potential investors at bay, and a better managed, more efficient Gazprom could attract the investment that is so sorely needed. Putin is working on a series of energy contracts with EU leaders that will benefit all parties. Russia would obtain the capital investment it needs to overhaul its out-of-date producing and exporting infrastructure, and Europe would obtain attractively priced gas supplies to meet increasing demand and diversify supply sources.

If Gazprom goes ahead with planned reductions in supply to Russia's Unified Power System, the power company will be forced to turn to Turkmenistan for natural gas at considerably higher prices. Although Gazprom's year-to-date gas exports are down from 1999 figures, profits are up by 60 percent because of the rise in foreign gas prices [***37***]. Gazprom has also talked of raising prices to a number of foreign customers, including Poland and Lithuania.

In addition to receiving lower prices domestically for its gas, Gazprom still struggles with the issue of nonpayment both domestically and within the EE/FSU. In one recent example of domestic nonpayment problems, Gazprom stopped supplies to a number of regions on September 30, 2000, just before the start of the heating season, because of consumers' nonpayment of bills. Included were the Siberian city of Omsk and the southern region of the North Caucasus republic of North Ossetia. Supplies to homes in North Ossetia had dwindled to the point that it was taking more than an hour to bring a kettle of water to a boil on a gas stove. If debts for gas already consumed can be rescheduled, North Ossetia hopes to see the resumption of deliveries for the winter [***38***]. During the 1999/2000 winter, supplies to Moldova were shut off twice by Gazprom for nonpayment. As of the end of September 2000, Moldova was hundreds of millions of dollars in debt to Gazprom [***39***].

In other countries, payment arrangements and/or barter deals continue to help satisfy the huge debt owed Gazprom. In December 2000, Russia and Ukraine worked out a restructuring of Ukraine's debt under which Ukraine has been given an 8-year grace period, with the debt to be repaid by the Ukrainian government in cash. In turn, Ukraine has provided Russia with some security guarantees on the transit of Russian gas to Europe through Ukraine, and Russia has guaranteed the supply of necessary quantities of gas to Ukraine [***40***].

These agreements are important to both Russia and Ukraine. Ukraine is the transit route for approximately two-thirds of Russian gas destined for European markets, and Russia contends that Ukraine has been siphoning off gas during transit for both internal use and resale. The agreement, if upheld, will put an end to that practice and could soften Russia's objections to the construction of a pipeline through Ukraine to deliver Russian supplies to Western Europe. Russia has instead supported a less direct route through Belarus, Poland, and Slovakia that bypasses Ukraine. Slovakia is already the world's second largest conveyor of natural gas, with up to 25 percent of the natural gas consumed in Western Europe crossing Slovakian territory [***41***]. The choice of routes has been contentious, with Poland until recently being opposed to a route that bypasses its strategic ally, Ukraine.

In an attempt to lessen its dependence on Russia, Ukraine intends to satisfy a portion of its gas demand with imports from Turkmenistan. Turkmenistan had ceased supplying Ukraine with gas in May 1999, because of mounting debt, but agreed to resume supplies in October 2000 after receiving $16 million in cash toward the debt. Payment for the resumed supplies will initially consist of 40 percent cash and 60 percent goods and services for the expansion and updating of Turkmenistan's oil and gas infrastructure [***42***]. Ukraine has agreed to make weekly advance payments of $7 million in cash and $9 million in goods and services to ensure timely payment [***43***]. While on the surface this agreement will diversify Ukraine's gas sources, some are concerned about the fact that the Turkmen gas still must pass through Russia en route to Ukraine, with transit fees under the control of Gazprom.

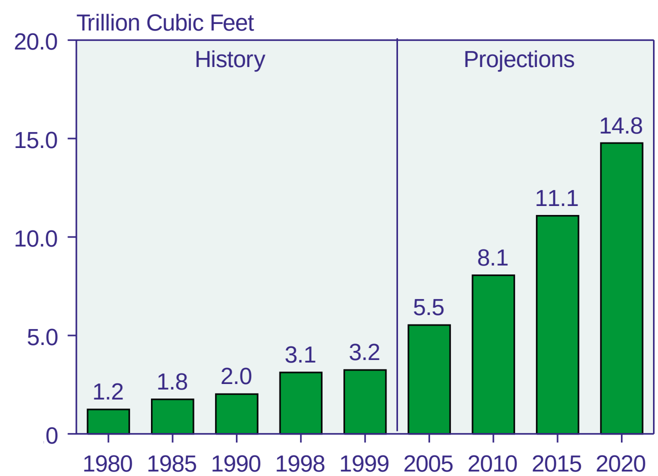
The move continues among other countries dependent on Russia to diversify their sources of supply, especially in light of Russia's looming shortfall. Poland has announced plans to cut imports from Russia by more than one third. Warsaw maintains that European suppliers are more reliable than Russia, and a new Polish law mandates that no one natural gas supplier may provide more than 49 percent of the country's natural gas supply. Poland's plans are to replace Russian supplies with Norwegian supplies transported via the Baltic Sea [***44***].

Central and South America

Natural gas reserves in Central and South America represent less than 5 percent of the world total; however, much of the region remains to be explored for gas, and new discoveries have accompanied recent exploration activity. The region continues to be an area of rapid gas development, and *IEO2001* projects that its gas use, facilitated by additional pipelines, will grow to 14.8 trillion cubic feet by 2020, at an average annual growth of 7.5 percent (Figure 44).

A great deal of gas market activity is occurring in the area referred to as the Southern Cone, or Mercosur (from *Mercado Comun del Sur*, the Southern Common Market

Figure 44. Natural Gas Consumption in Central and South America, 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, January 2001). **Projections:** EIA, World Energy Projection System (2001).

involving Brazil, Argentina, Paraguay, and Uruguay, with Chile and Bolivia as Associated Members), which is becoming a significant pipeline gas market. Further north, the approval of expansion plans for Atlantic LNG, located in Trinidad and Tobago and new gas finds there are also important events. Activity throughout the region underscores the changing dynamics of international natural gas trade (Figure 45).

Two developments in Latin America highlight the potential for increased use of imported LNG in smaller markets. In July 2000, Atlantic LNG began natural gas deliveries from Trinidad and Tobago to Puerto Rico, where the gas is used largely for power generation. Also in the summer of 2000, an AES (Applied Energy Services) subsidiary and BP Amoco signed an agreement to send LNG from Trinidad to the Dominican Republic. The deal involves 720,000 metric tons of LNG per year arriving in the Dominican Republic via a new LNG import terminal (reportedly now under construction) from as early as the end of 2002. A second terminal and associated power project were announced by Union

Figure 45. Major International Natural Gas Pipelines in South America

Source: Adapted from "South America: A Flair for Gas," *Petroleum Economist*, Vol. 67, No. 5 (May 2000), pp. 30-34.

Fenosa and Enron in October 2000, with construction expected to begin in the first part of 2001. Gas demand in the Dominican Republic may not be sufficient, however, to support two LNG import terminals [***45***].

The Trinidad and Tobago Atlantic LNG facility is initiating new trade routes with contracts that cover smaller volumes than have been common in the Asian dominated LNG trade. The Atlantic LNG export project is also set to expand, having received formal approval from the Trinidad and Tobago government in the first part of 2000. Plant capacity is set to increase by 6.5 million tons per year to nearly 9.5 million tons per year. Of the expanded production, 55 percent will supply the Spanish market (via Enagas) and 45 percent will go to Southern Natural Gas (Sonat) of Georgia. The expansion, due for completion in 2003, will cost $1.1 billion and will lead to projected tax revenues for the Trinidad government of $240 million annually over a 20-year period [***46***]. Ongoing exploration continues to delineate more gas resources in the area, including two major finds reported by BP Amoco. BP's second discovery, announced in September 2000, could turn out to be the largest yet made in Trinidad and Tobago (on the Red Mango prospect), with an estimated 3 trillion cubic feet of gas and 90 million barrels of condensate [***47***].

Proposals for two more LNG export facilities in the American Atlantic basin, both in Venezuela, were discussed during 2000. Venezuela's government has decided to emphasize gas business via the state company, Petroleos de Venezuela (PDVSA). PDV Gas and Enron signed a memorandum of understanding (MOU) to construct a single-train LNG plant near San Jose with a capacity of 2 metric tons per year. Despite a targeted startup in 2003-2004, arrangements for the project are not yet finalized. The other proposal is a resurrection of the previously canceled Cristobal Colon project involving ExxonMobil, Royal Dutch/Shell, and Mitsubishi, using gas from the Gulf of Paria. The companies signed an MOU with PDVSA regarding an LNG plant with a capacity of 4 metric tons per year, which is intended to export gas to U.S. and Caribbean markets from the state of Sucre. This project, now called Project Venezuela Liquefied Natural Gas (PVLNG), has been targeted for a 2005 startup. Industry experts are skeptical, however, that either project will find a market to take the gas before 2010 [***48***].

In Peru, government actions are having a different impact on gas development. The government awarded a contract for development of the Camisea gas fields (300 miles east of Lima) in February 2000 after many delays. The winning consortium included Argentina's Pluspetrol Resources (holding a 40-percent equity share), Hunt Oil's Peru subsidiary (40 percent share), and South Korea's SK Sucursal Peruana (20 percent share). Argentine Pluspetrol, which will operate Camisea production, offered the highest royalty in its bid (37.24 percent) and narrowly beat the only other offer (35.5 percent by France's Elf). The royalty offers in both bids were substantially higher than the 10-percent minimum set by the government. The contract awardees are considered small players in the industry (relative to the giants like Shell and Mobil, which withdrew from the project after negotiations with the government failed), and there is some speculation that field development will proceed slowly and include difficulties in securing financing. The winning consortium, which has a 40-year concession to develop the reserves, expects to meet a government goal of transporting gas to Lima by 2003.

The award of a related transportation-distribution contract was also delayed repeatedly by the Peruvian government during 2000. Political instability in Peru has played a large role in the delays. This second contract was awarded in October 2000 to the one and only bidder, a consortium involving Argentina's Techint, Algerian Sonatrach, a Peruvian construction firm (Grana y Montero), and the members of the Argentine Pluspetrol upstream consortium named above. The government guarantees a 12-percent return on investment for transportation and distribution to and within Lima [***49***].

Brazil, like Venezuela, has a large and powerful state hydrocarbons company, Petrobras. In March 2000 the president of Petrobras signed a contract for increased gas deliveries from Bolivia by 2004. For the first half of 2000, however, the Bolivia to Brazil (BTB) gas pipeline remained underutilized, partly because of slow and delayed power plant construction. Petrobras, which is under contract to pay for imports from the line whether or not it uses the gas, opposed requests from other companies seeking third-party (open) access to the pipeline capacity [***50***].

Petrobras also signed an MOU regarding a proposed pipeline it would underwrite in Bolivia. Recent discoveries have increased Bolivia's reserves, and the planned pipeline would link Yacuiba in gas-rich Tarija to the existing BTB pipeline. The new pipeline would run parallel to the existing Yabog line operated by Transredes (controlled by Shell and Enron), and thus it is not surprising that concerns were raised over the MOU, which may favor one investor over others [***51***].

Delivering Argentine gas to Brazil, the Transportadora de Gas del Mercosur (TGM) pipeline began operations in the second half of 2000, providing the first direct interconnection of Brazilian and Argentine gas networks. The 24-inch line from Aldea Brasilera in the northern Argentine province of Entre Rios to Brazil will supply gas to a new 600-megawatt power plant at Uruguaiana, Rio Grande do Sul [***52***]. Transportadora SulBrasileira de

Gas (TSB), which connects TGM to Uruguaiana in Brazil, is now planning a second phase for completion in 2001 involving an extension from Uruguaiana to Porto Alegre, including interconnection with the Bolivia-Brazil pipeline. Gasoducto Cruz del Sur is also pursuing a connection with Porto Alegre via extension from Colonia, Uruguay [***53***]. Plans for an LNG terminal in Brazil have also been announced, although there is no clear timetable for development. Gaspetro of Petrobras and Shell have announced plans to build an import terminal at Suape, the deepwater port and industrial complex in northeast Brazil [***54***].

Asia

Gas market activity in Asia during 2000 reflected ongoing, if uneven, recovery from the economic crisis that affected the region from 1997 to 1999. Many oil and gas importers in the region were adversely affected by high oil prices during 2000. Although LNG prices in Asia are generally linked to crude oil prices, LNG trade is also dominated by long-term contracts, and high oil prices did not slow the LNG movements that currently dominate gas trade in the region. It is important to note what did not happen in the region: plans for additional LNG imports did not move forward rapidly, nor did 2000 become an important year for the signing of long-term sales agreements that would solidify future LNG trade.

The *IEO2001* reference case projects that natural gas consumption in the whole of Asia (both industrialized and developing) will grow by an average of 5.0 percent per year, increasing Asia's consumption to 26.6 trillion cubic feet in 2020 from 9.6 trillion cubic feet in 1999. The growth in developing Asia is expected to far outpace that in the industrialized countries of the region (Figure 46).

Industrialized Asia

For the countries of industrialized Asia, natural gas consumption is expected to rise from 3.6 trillion cubic feet in 1999 to 5.4 trillion cubic feet in 2020. Australia—which has large, expanding gas reserves and further resource potential—continued to pursue supply projects during 2000, including a proposal for a gas-to-liquids project. Japan, with recent power sector deregulation, has not moved to fully renew LNG contracts that will be expiring in a few years.

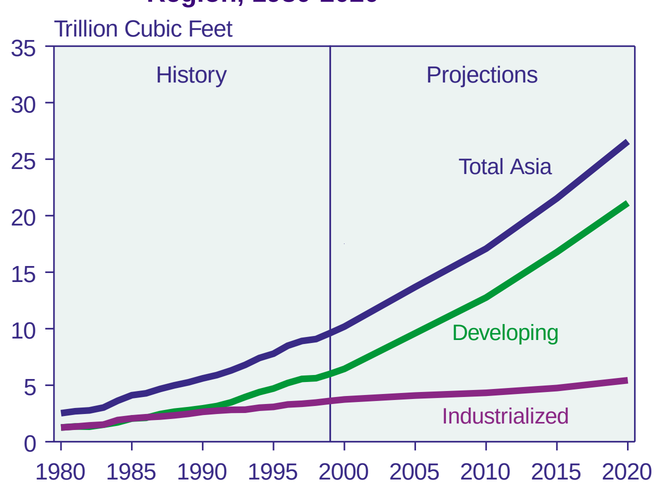
Australia, Asia's third largest producer of natural gas in 1999, also has large undeveloped gas resources, some in remote areas. During 2000, Australia continued to make discoveries of significant gas resources in the remote northwest. For example, discoveries by the West Australian Petroleum (WAPET) consortium in the Gorgon gas fields could eventually add several trillion cubic feet of gas to existing reserves [***55***].

Many of the gas-related developments in Australia during 2000 were aimed at bringing Australian gas to markets. There is more than one ongoing effort to build additional LNG production facilities, although developers have not yet secured buyers for the volumes of LNG that would enable them to move forward. Marketing efforts continue, particularly those oriented toward China and Taiwan. For example, Australia LNG has signed an MOU with Tuntex Gas Corporation for LNG trade, but it depends on the ability of Tuntex to secure buyers for the gas in Taiwan [***56***].

In addition to LNG, new proposals were made in 2000 to use Australia's northwest gas domestically. Austeel announced that it is planning to build a major iron and steel plant in the region and that it has signed an initial MOU to use gas from the Northwest Shelf. If completed, this would be the biggest gas supply deal for Western Australia in 20 years [***57***]. The Sweetwater gas-to-liquids project[8] planned by Syntroleum would also use Northwest Shelf gas domestically, converting it to liquid products. To be located on the Burrup Peninsula in Western Australia's Pilbara, the 10,000-barrel-per-day Sweetwater project now includes Clough engineering as a local partner, with German Tessag INA as the contractor for engineering, procurement, and construction [***58***].

Because Australia's abundant gas resources are concentrated in the remote northwest, some developers are

Figure 46. Natural Gas Consumption in Asia by Region, 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, January 2001). **Projections:** EIA, World Energy Projection System (2001).

[8]For more information about gas-to-liquids technology and proposed projects, see Energy Information Administration, *International Energy Outlook 2000*, DOE/EIA-0484(2000) (Washington, DC, March 2000), p. 59.

continuing to promote a pipeline project to import gas from Papua New Guinea to gas-poor northeastern Australia (the province of Queensland). Chevron and its partners in the pipeline project have asked the Australian government to review and clarify applicable fiscal and tax conditions, which could affect the project's financial viability. (Developers said the project was potentially threatened by a debated tax change in the cutoff for accelerated depreciation.)

During summer 2000, the Queensland government announced a new "cleaner energy strategy," which could help the Chevron pipeline project succeed. The government strategy requires 15 percent of power needs to be met from gas-fired or renewable energy by 2005. The Queensland government also announced that no new licenses would be issued to coal-fired power plant projects unless absolutely necessary. In addition, the government is said to be in talks with the consortium building the PNG-Queensland pipeline (involving AGL and Petronas) about possibly taking an equity share in a portion of that project [***59***].

In Japan, as in Europe and the United States, deregulation is changing both the gas and power industries as gas companies move into the power sector and power companies pursue gas ventures. Chubu Electric and Iwatani announced plans for a joint venture to sell retail LNG to large industrial plants, using tank trucks for transportation from the LNG terminal next to their Kawagoe power plant in Mie Prefecture, central Japan. They anticipate that sales could begin by April 2001. In mid-March 2000, Tokyo Gas, Osaka Gas, and Nippon Telegraph and Telephone (NTT) said that they were thinking of forming a new large-scale joint venture to supply electricity [***60***]. Also, many of Japan's power companies now have plans that call for reductions in the natural gas share of power generation and increases in the nuclear and coal shares.

Developing Asia

Developing Asia includes the first, second, and fourth most populous countries in the world—China, India, and Indonesia. As a region, developing Asia accounts for more than 50 percent of the world's population, roughly 10 percent of its GDP, and about 7 percent of its natural gas consumption. Strong growth in both GDP and gas use are expected for the region, which could account for about 13 percent of global gas use by 2020. Much of the gas that will be used in developing Asia is expected to cross international borders to reach markets, thus contributing to growing international gas trade. Major gas trade developments during the past year involve pipeline projects in Southeast Asia, prospects for LNG import terminals in China and India, and plans for additional LNG export facilities in Malaysia, Australia, and Indonesia. Countries with significant development of gas resources for domestic use include Australia, China, Malaysia, Pakistan, the Philippines, and Thailand.

China

At the beginning of January 2000, the Chinese government formally approved its first plan to import LNG, into Guangdong in the south. With a targeted startup date of 2005, the LNG project will involve China National Offshore Oil Corporation (CNOOC), holding a likely 36-percent equity share. An additional 34-percent share in the project would be held by local parties including Guangzhou Gas Company, Dongguan Gas, Foshan Gas, Guangdong's Provincial Power Bureau, and Shenzhen Investment Management Company. The remaining stake probably will be offered to foreign private investors [***61***].

Toward increasing domestic gas supply, Shell, BP Amoco, and Enron all have agreements to develop gas resources and infrastructure in China [***62***]. Expansion and integration of pipeline infrastructure will be important to increasing gas use in China (Figure 47). China also announced during 2000 the discovery of what it is calling the country's biggest natural gas field. Located in the northern part of the Tarim Basin in Xinjiang Province, the find is estimated by China to hold more than 7 trillion cubic feet of gas.

India

India, developing Asia's other giant, is another country where rapid growth in gas consumption is expected (Figure 48). Many LNG import schemes are proposed for the country, and there are frequent announcements about them, but few are under construction or making concrete progress. To facilitate gas development, India needs and continues to pursue comprehensive policies for natural gas and, specifically, LNG. However, related policymaking and reform (particularly in the natural gas and power sectors) are proceeding slowly in India's complex democracy.

In the first half of 2000, a committee was established to formulate a comprehensive LNG policy for India, and by August 2000 a draft policy had been issued. Some proposals in the draft policy call for the central government to take a much stronger role in coordinating LNG imports. The draft also contains guidelines to ensure that foreign investors in Indian LNG shipping will maintain Indian involvement and technology transfer. It is not yet clear how the government would handle existing contracts and agreements that are not aligned with the new guidelines [***63***].

Meanwhile, Enron's project to build an LNG terminal at Dabhol is under construction, and Petronet moved forward in 2000 toward finalizing aspects of its first LNG

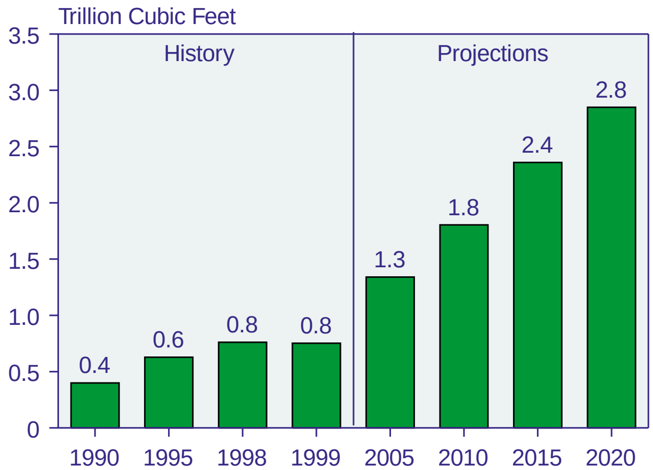
Figure 47. China's Major Natural Gas Pipelines

Source: Fesharaki Associates Consulting and Technical Services and East-West Consultants International, Ltd., *China's Natural Gas to 2015*, Multi-Client Study (Honolulu and Singapore, October 2000), p. 4-10.

import scheme. The evolution of Petronet in India is significant because it is a government-led undertaking with substantial state participation in an arena where private companies are competing fiercely. Rasgas, the Qatari LNG supplier, is taking a cross-investing share in Petronet, and several Indian public-sector companies will have a total of 50 percent equity [***64***]. In October 2000, Petronet and Rasgas agreed to postpone until December 2003 the first LNG deliveries under a sale purchase agreement (SPA) [***65***]. One state company, the National Thermal Power Corporation, has promoted a private-sector proposal for a terminal at Pipavav in Gujarat, and it is ready to take equity in the project, which also involves British Gas [***66***].

India's LNG import schemes tend to involve gas sales to power producers as a critical component; however, many of India's state electricity boards (utilities) are in poor financial condition, in part because of their practice of selling power at subsidized rates. Until power reform issues are resolved, LNG projects in India will struggle to secure gas buyers and project financing in a subsidized environment. For example, in Tamil Nadu on India's southernmost east coast, efforts have continued to solidify a project involving the Dakshin Bharat Energy Consortium and its Ennore terminal. The Ennore project appeared to be in trouble at one point during 2000 because of the financial status of the Tamil Nadu Electricity Board (TNEB). TNEB could not provide

Figure 48. Natural Gas Consumption in India, 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, January 2001). **Projections:** EIA, World Energy Projection System (2001).

escrow cover for power purchase payments, let alone purchase the entire output as earlier promised. Time was also running out on a deadline for locking in the LNG price with its Middle Eastern supplier.

Before the end of September 2000, investors in the Tamil Nadu project (including CMS Energy) announced that they had concluded a joint development agreement with the Power Trading Corporation of India. The agreement includes a government commitment to institute a "payment security mechanism" to guarantee firm purchase of power from the associated 1,850-megawatt gas-fired power plant. The agreement also has a noteworthy diplomatic element, having been concluded in Washington, DC, and involving as signatories U.S. Commerce Secretary Norman Mineta and Indian Finance Minister Yashwant Sinha [***67***].

Other Asia

While China and India are on the verge of becoming key LNG importers in Asia, Malaysia is proceeding in a somewhat unusual manner with plans to build the country's third LNG plant (known as MLNG III or MLNG Tiga). Sponsoring consortium members including a Petronas subsidiary, and Kellogg Brown & Root of the United States have signed an engineering, procurement, construction, and commissioning contract for the plant without yet having contracts from buyers for all the LNG that will be produced. The ability to finance and build LNG plants without purchase commitments is new in the LNG industry [***68***].

In Malaysia and other parts of Southeast Asia, including Thailand, Indonesia, and Singapore, plans continue to expand cross-border natural gas pipelines. However, the timing of a proposed pipeline to deliver gas from a Malay-Thai joint development area (JDA) to both countries now seems to be in question. First, it is unlikely that Thailand will be able to take its commitment for gas from the JDA for several years due to a lack of domestic demand. Second, Malaysia, which was expected to take Thailand's share of JDA gas, has decided to buy gas from Indonesia's south Natuna resources beginning in 2002 [***69***].

Elsewhere, Singapore Power and Indonesia's Pertamina have initialed a contract confirming their plans to proceed with a pipeline from Sumatra to Singapore, where delivered gas will be used primarily for power generation in Singapore's deregulating electricity market [***70***]. Another pipeline is already under construction and ahead of schedule to begin delivering gas to Singapore from Indonesia's Natuna West gas field sometime during 2001. Indonesia, also an LNG exporter, continues to both deplete and add to its gas resources. Two trains at the Arun LNG export facility were shut down during 2000 due to field depletion, while Unocal reported a significant gas discovery, estimated by investors at 2 to 3 trillion cubic feet.

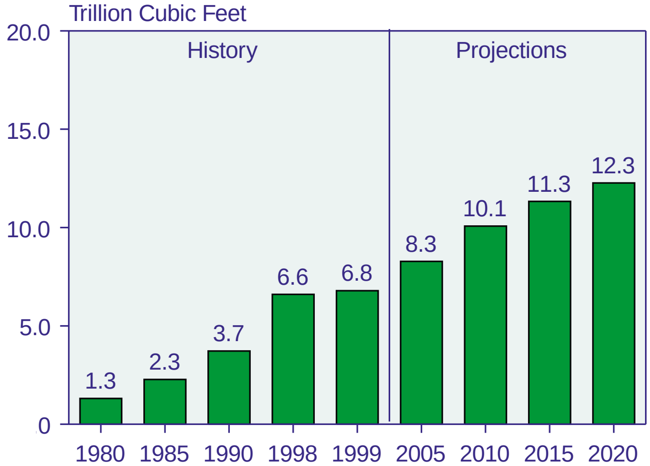
Middle East

The Middle East region has the second largest natural gas reserves after the FSU, amounting to 1,855 trillion cubic feet as of January 1, 2001. Iran, Qatar, Saudi Arabia, and the United Arab Emirates (UAE) have the second, third, fourth, and fifth largest reserve holdings in the world, respectively, following Russia. Already a strong producer and growing exporter of natural gas, the Middle East increasingly seeks to develop domestic gas markets. The *IEO2001* reference case projects a near doubling of Middle East gas consumption between 1999 and 2020, from 6.8 trillion cubic feet to 12.3 trillion cubic feet (Figure 49).

Estimates of gas resources in the Middle East also continue to grow. Iran's IRNA news agency has reported the discovery of a new gas field, known as Homa, containing an estimated 6.7 trillion cubic feet (and 82 million barrels of gas liquids). The onshore field is located about 30 miles north of the port of Asaluya (Bandar-e-Asulayeh) on the Persian Gulf in the southern Fars province. Nearby, another gas field, Tabnak, was found earlier in the year, with estimated reserves of 15.7 trillion cubic feet of gas and 240 million barrels of condensate [***71***].

During 2000, Iran's National Iranian Oil Company (NIOC) signed an agreement with Italy's Eni for the fourth and fifth development phases of the giant South Pars field, a deal worth about $3.8 billion [***72***]. British Gas (BG) signed a joint venture agreement with Iran's Oil Industries Engineering and Construction (OIEC) to pursue both domestic gas projects and LNG export from

Figure 49. Natural Gas Consumption in the Middle East, 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, January 2001). **Projections:** EIA, World Energy Projection System (2001).

Iran using gas from South Pars at the country's southern border. BG would export LNG to its receiving terminal planned for Pipavav in northwest India starting around 2006 [***73***]. Iran may also seek further gas development with other foreign investors, including Shell or BP.

Across the border from Iran's South Pars, the extraordinarily large gas resources extend to Qatar's North Field. Another plan to increase gas use in the Middle East, the Dolphin project, involves piping gas from Qatar to Abu Dhabi, Dubai, and eventually to Oman. Although the developer (UOG, or the United Arab Emirates Offsets Group) had hoped to start construction on the Dolphin project in 2000, it did not reach agreement with Qatar on a transfer price for the gas. In March 2000, UOG agreed to share equity in the project with Enron of the United States and the Franco-Belgian group, Total Fina Elf, which will split a 49-percent share [***74***]. Abu Dhabi, itself an LNG exporter, did agree in early 2000 to the construction of a 67-mile gas pipeline to Dubai's free trade zone, Jebel Ali. Abu Dhabi's gas company, Atheer (a subsidy of the national oil company), announced that work would be completed in early 2001 [***75***].

Saudi Arabia also has plans to develop domestic natural gas use by restarting foreign direct investment in its gas sector. In August 2000, a number of short-listed companies submitted bids for upstream and integrated gas projects, followed by high-level meetings with the Saudis. The Saudi negotiating team hopes to sign initial agreements with investors and begin detailed negotiations in 2001 [***76***]. Saudi Aramco also signed a contract with Foster Wheeler at the beginning of 2000 to provide preliminary work on the Haradh gas project. Set to begin operation in 2004, the facility will produce 1.4 billion cubic feet of gas per day for domestic use [***77***].

In early 2000, the first commercial gas deposit was discovered offshore Israel by British Gas with two local partners, Isramco and Delek. In April, Samedan (operating in partnership with Avner, Delek, and RB Mediterranean) made another important gas discovery about 15 miles off Israel's southern coast. Samedan is estimating that reserves at the Mari-B structure will exceed 1 trillion cubic feet. Israel aims to increase gas-fired power generation to avoid a looming electricity crisis. As part of a related gas development effort, four consortia have submitted bids to build Israel's natural gas system [***78***].

During 2000, both Qatar and Oman brought new LNG export facilities on stream and pursued domestic gas development. In Qatar, RasGas began production from its second LNG train, doubling capacity at the Ras Laffan facility to 5 metric tons per year. Most of the gas will go to Korea under a long-term contract, but excess LNG will also be available for sale. On the domestic front, Qatar signed a contract with ExxonMobil to develop North Field gas for local industry and a planned independent power plant. Gas may also be piped from Qatar to Kuwait for domestic use [***79***].

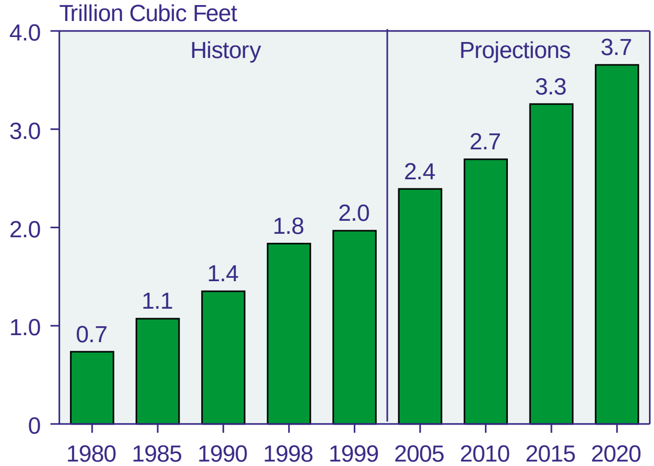
Oman, which produced its first LNG in December 1999, began production at the second train of its facility in the second quarter of 2000. LNG exports will go to Korea, Japan, and India (Dabhol). Also in Oman, seven companies have submitted bids to build two new gas pipelines from inland gas fields to the coastal cities of Sohar and Salalah. The companies include U.S.-based Willbors, Italy's Saipem / Snamprogetti / CCC, Technip Germany, India's Dodsal, Argentina's Techint, and South Korea's LG / Hyundai and SK / Daewoo [***80***].

Africa

Africa's gas reserves, estimated at 394 trillion cubic feet, account for nearly 8 percent of global reserves. Egypt, Algeria and Nigeria have a combined 319 trillion cubic feet of reserves or about 80 percent of the total. Gas production activity is concentrated in north and west Africa, where proposed export projects and plans for domestic use are also accumulating. In the western part of Africa, especially Nigeria, production of associated gas has risen with development of crude oil resources and reductions in gas flaring.

The *IEO2001* reference case projects that natural gas consumption in Africa will increase by 7.5 percent per year on average from 1999 to 2020. Total gas use in Africa is projected to rise from 2.0 trillion cubic feet in 1999 to 3.7 trillion cubic feet in 2020 (Figure 50).

Figure 50. Natural Gas Consumption in Africa, 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, January 2001). **Projections:** EIA, World Energy Projection System (2001).

In Algeria there are new plans for gas development to monetize the gas reserves and resources that grew in the 1990s with successful exploration. During the first quarter of 2000, BP Amoco and Sonatrach (in a 50:50 joint venture) agreed to proceed with the $2.5 billion development of the In Salah gas fields in the central Algerian Sahara Desert, which contain more than 7.5 trillion cubic feet. First deliveries are due in 2003 to Italy, where the gas has already been assigned to Enel in an earlier Sonatrach deal. Edison Gas, the independent marketer in Italy, may purchase additional volumes and already has an agreement in principle [***81***].

In the summer of 2000, a noteworthy new type of contract was signed for a $1 billion development project in eastern Algeria's Ohanet gas/condensate fields, which contain more than 3.4 trillion cubic feet. A consortium led by BHP (known earlier as Broken Hill Proprietary Company) signed a "risk service contract" (RSC) with Sonatrach. The RSC states partner entitlements in monetary terms, in contrast to a production sharing contract, which involves monetary and volume terms. (BHP, for example, has no entitlement to pipeline gas or associated revenue, although it does have entitlement to a share of the LPG and condensate produced.) Sonatrach will export the natural gas via the Mediterranean pipeline and as LNG [***82***].

Algeria's government is considering privatization of domestic electricity and gas distribution, and a law to privatize mining has already been approved. The measures are in part a response to economic and financial difficulties in the country, which currently suffers from a 30-percent unemployment rate and uses 40 percent of its total export revenue to service foreign debt. In September 2000, Algerian Prime Minister Ahmed Benbitour resigned, reportedly because President Bouteflika was dissatisfied with the slow pace of Benbitour's economic reform efforts [***83***].

Both Egypt and Angola have plans to develop large gas resources for LNG export, but firm buyers for their exports are still needed. Egypt has signed an agreement with Union Fenosa of Spain, which would invest in the facility. At the same time, gas resources are growing in Egypt, where British Gas announced a significant gas and condensate discovery made together with Edison in the West Delta Deep Marine Concession, located 40 miles northeast of Alexandria [***84***].

In addition to developments in north and west Africa, South Africa has had an important gas find and reached agreement to develop offshore gas. An estimated 2.5 trillion cubic feet of natural gas was discovered about 50 miles off of South Africa's west coast by Forest Oils and Anschutz. The gas lies at relatively shallow depths, with the potential for oil still to be found, and is the most important find since the Mossgas discoveries of the early 1980s [***85***]. The Mossgas resources will be further developed by British-based Dresser Kellogg Energy Services, which will drill wells and provide transport and process systems for the gas. The official export credit agency of the United Kingdom, Export Credits Guarantee Department (ECGD), has reported that it will underwrite the financing for the project [***86***].

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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,[9] was 15 percent higher than coal use in 1980, it was lower than in any year since 1984 (Figure 51). The *International Energy Outlook 2001* (*IEO2001*) reference case projects some growth in coal use between 1999 and 2020, at an average annual rate of 1.5 percent, but with considerable variation among regions.

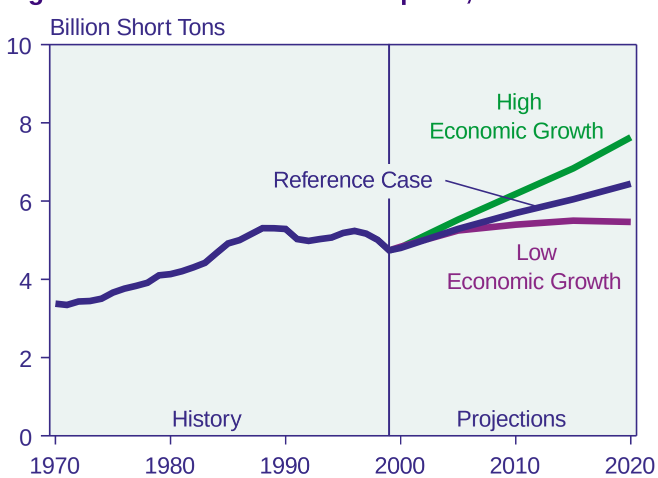
Coal use is expected to decline in Western Europe, Eastern Europe, and the former Soviet Union (FSU). Increases are expected in the United States, Japan, and developing Asia. In Western Europe, coal consumption declined by 42 percent between 1985 and 1999, displaced in large part by the growing use of 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 44 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 *IEO2001* reference case, the coal share of total energy consumption is projected to fall to 19 percent by 2020 (Figure 52).

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 92 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 53).

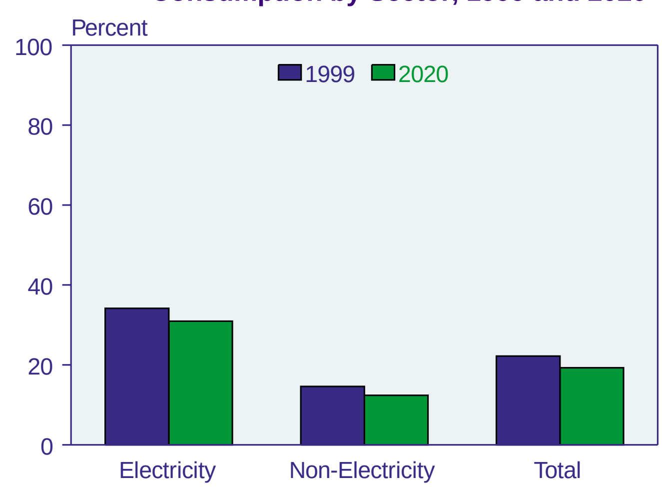
Coal consumption is heavily concentrated in the electricity generation sector, and significant amounts are also

Figure 51. 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, January 2001). **Projections:** EIA, World Energy Projection System (2001).

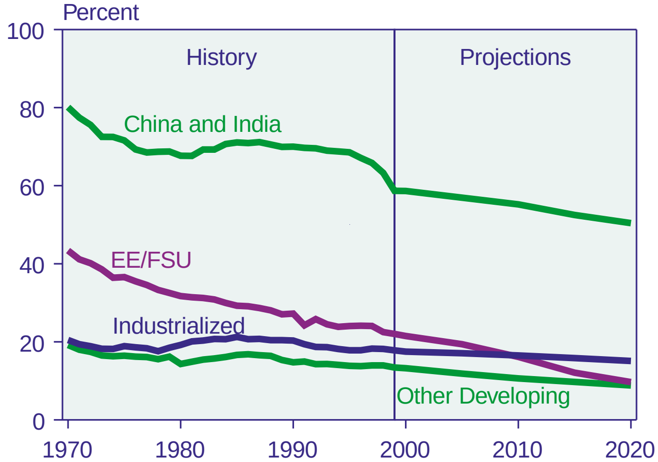
Figure 52. Coal Share of World Energy Consumption by Sector, 1999 and 2020



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

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

Figure 53. 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, January 2001). **Projections:** EIA, World Energy Projection System (2001).

used for steel production. More than 55 percent of the coal 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 alternative sources of energy. Consumption of coking coal is projected to decline slightly in most regions of the world as a result of technological advances in steelmaking, increasing output from electric arc furnaces, and continuing replacement of steel by other materials in end-use applications.

The *IEO2001* 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. International prices for steam coal (used in power generation) declined sharply in 1999 amid strong competition among exporters, with increasing exports from Australia and Indonesia and decreasing exports from the United States and Canada. In 2000, international coal markets were affected by sharp increases in ocean shipping rates, a recovery in coal export prices during the second half of the year, and a substantial increase in overall coal trade. In Asia, some price increases reflected a tighter market, caused in part by coal miner strikes in Indonesia and Australia and China's failure to meet export commitments.

Highlights of the *IEO2001* projections for coal are as follows:

- World coal consumption is projected to increase by 1.7 billion tons, from 4.7 billion tons in 1999 to 6.4 billion tons in 2020. Alternative assumptions about economic growth rates lead to forecasts of world coal consumption in 2020 ranging from 5.5 to 7.6 billion tons (Figure 51).
- Coal use in developing Asia alone is projected to increase by 1.7 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 92 percent of the world's total projected increase in coal use, on a Btu basis.
- The share of coal in world total primary energy consumption is expected to decline from 22 percent in 1999 to 19 percent in 2020. The coal share of energy consumed worldwide for electricity generation is also projected to decline, from 34 percent in 1999 to 31 percent in 2020.
- World coal trade is projected to increase from 548 million tons in 1999 to 729 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) [***2***]. Recent studies on the health effects of mercury 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 [***3***].

In 1998, about 230 gigawatts of coal-fired capacity around the world—about 44 percent of it in the United States—used FGD technologies [***4***]. 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 1995 indicated that only about 3 percent of coal-fired generating capacity (at that time, less than 4 gigawatts out of a total of 140 gigawatts) had FGD equipment in place [***5***].

In addition to sulfur dioxide, increased restrictions on emissions of nitrogen oxides, particulates, and carbon dioxide are now appearing and are likely to increase. 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 gas-fired generating plants. Yet the future is also unclear for nuclear and hydropower, which compete with coal for baseload power generation. Some countries have proposals or plans to restrict and even eliminate nuclear power, which is frequently a target of public protest and opposition. Large-scale hydropower is also increasingly unpopular, and in some places the available resources have already been heavily exploited. Limited prospects for nuclear and / or hydropower capacity in some areas could potentially increase coal use for power generation.

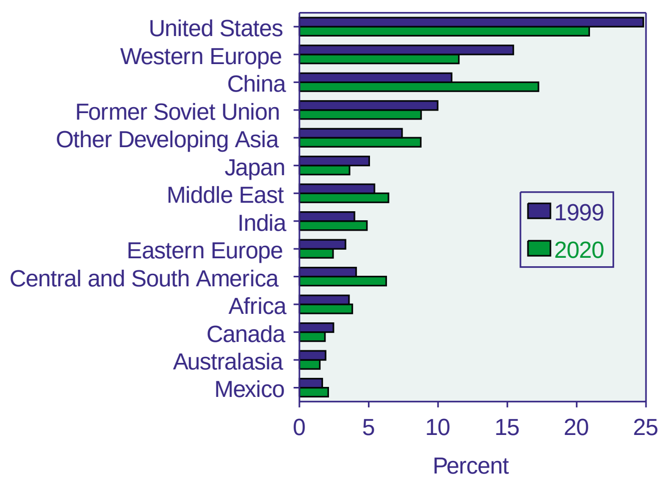
By far the most significant emerging issue for coal is the potential for a binding international agreement to reduce emissions of carbon dioxide and other greenhouse gases. On a Btu basis, the combustion of coal produces more carbon dioxide than the combustion of natural gas or of most petroleum products.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

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 *IEO2001* forecast to decline to 21 percent by 2020, while China's share is projected to increase to 17 percent (Figure 54). Worldwide, coal is projected to continue as the second largest source of carbon dioxide emissions (after petroleum), accounting for roughly 30 percent of the world total in 2020.

Reserves

Coal is the most abundant of the fossil fuels, and its reserves are also the most widely distributed. Estimates of the world's total recoverable reserves of coal in 1999, as reported by EIA, are essentially unchanged from 1998, at about 1,089 billion tons.[10] The resulting ratio of coal reserves to production exceeds 220 years, meaning

Figure 54. 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, January 2001). **2020:** EIA, World Energy Projection System (2001).

[10]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.

that at current rates of production (and no change in reserves), coal reserves could last for another two centuries. The distribution of coal reserves around the world varies notably from that of oil and gas, in that significant reserves are found in the United States and the FSU (Figure 55) but not in the Middle East. The United States and the FSU each have roughly 25 percent of global coal reserves. China, Australia, India, Germany, and South Africa each have between 6 and 12 percent of world reserves [*6*].

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 have supplied approximately 85 percent of globally traded coking coal during recent years (see below, Table 17).

At the other end of the spectrum are reserves of low-Btu lignite or "brown coal." Coal of this type is not heavily traded because of its relatively low heat content and other problems relating to transport and storage. In 1999, lignite accounted for 19 percent of total world coal production (on a tonnage basis), and the top three producers accounted for 41 percent of world lignite production: Germany (178 million tons), Russia (99 million tons), and the United States (84 million tons). On a Btu basis, lignite deposits show considerable variation. Estimates by the International Energy Agency for 1998 show that the average heat content of lignite produced in member countries of the Organization for Economic Cooperation and Development (OECD) varied from a low of 4.8 million Btu per ton in Greece to a high of 12.3 million Btu per ton in Canada [*7*].

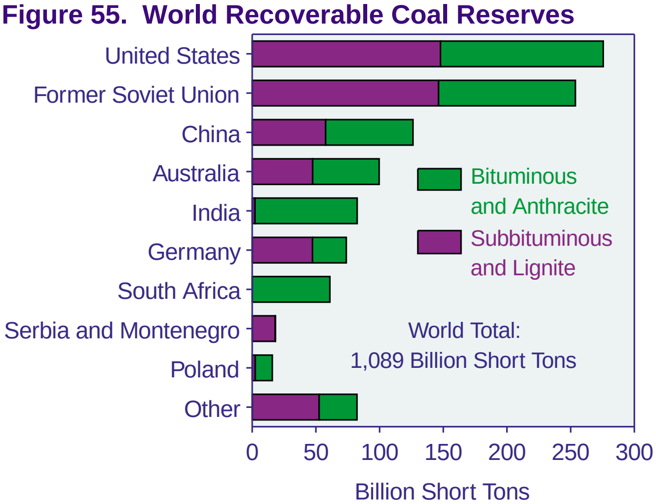
Regional Consumption

Developing Asia

As a region, Asia accounted for 36 percent of the world's coal consumption in 1999. China, the world's largest consumer of coal, accounted for almost 23 percent of global coal consumption in 1999. Large increases in coal consumption are projected for China and for India (Figure 56), which also has sizable coal reserves, based on an outlook of strong economic growth for both countries and the expectation that much of their increased demand for energy will be met by coal, particularly in the industrial and electricity sectors. The *IEO2001* forecast assumes no changes in environmental policies in the two countries. It also assumes that necessary investments in the countries' mines, transportation infrastructure, industrial facilities, and power plants will be made.

The electricity sector accounted for roughly 30 percent of China's coal consumption in 1999 on a Btu basis. By 2020, coal use for electricity generation in China is expected to rise to 17.0 quadrillion Btu from 5.9 quadrillion Btu in 1999. However, 59 percent of the total increase in coal consumption by 2020 is projected to occur in the non-electricity sectors, including industrial applications and the manufacture of coal coke for use in making steel and pig iron. In 1998, China was the world's leading producer of both steel and pig iron [*8*].

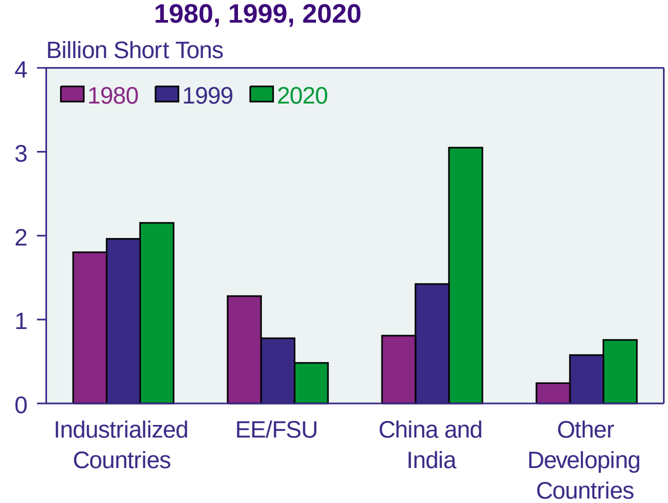
Figure 55. World Recoverable Coal Reserves



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, January 2001), Table 8.2.

Figure 56. 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, January 2001). **2020:** EIA, World Energy Projection System (2001).

(Pig iron offers a more direct link to overall coal use, as its production requires the use of coal coke and coal. Overall steel production includes steel manufactured by electric arc furnaces, which bypass the use of coal.) According to these forecasts, China would account for 40 percent of world coal use in 2020.

Energy consumption in India is also dominated by coal, and more than two-thirds of the coal consumed is used in the power sector, where most growth in coal demand is projected to occur. Coal use for electricity generation in India is projected to rise by 2.1 percent per year, from 4.5 quadrillion Btu in 1999 to 6.9 quadrillion Btu in 2020. A single company, Coal India Limited, has dominated domestic production in India, and now the government is seeking to deregulate coal distribution and some coal prices, which could affect consumption when the policies are implemented.

The rest of developing Asia is a huge and diverse area, accounting for more than 15 percent of the world's current population and 11 percent of the increase in primary energy use projected in the *IEO2001* reference case. Outside China and India, however, coal is expected to play a less prominent role in the energy mix. Coal use in other developing Asia is projected to increase by 2.0 quadrillion Btu between 1999 and 2020, as compared with a projected increase of 32.3 quadrillion Btu for the world. For other developing countries in Asia, as in India, coal is used predominantly for electricity generation. The coal share of energy used for power generation in other developing Asia (excluding South Korea) rose from 28 percent in 1995 to 29 percent in 1999 and is projected to continue growing to 31 percent in 2020.

South Korea is a significant coal user in both the power and steel industries, although electricity generation there is also based on nuclear power and natural gas. South Korean Pohang Iron & Steel (POSCO) is the world's largest steel producing company, buying coal on both long-term and one-year contracts [***9***]. Coal consumption in South Korea is expected to increase from 1.4 quadrillion Btu in 1999 to 1.9 quadrillion Btu in 2020, accounting for more than 25 percent of the projected increase in developing Asia outside China and India.

Taiwan is the next largest coal user in other developing Asia. Its electricity industry is similar to Korea's in that coal plays an important role together with nuclear power and imported natural gas. Taiwan's state power generating company, Taipower, purchases three-quarters of its coal needs through long-term contracts (primarily with Australia) to supply several very large coal-fired power plants. These include Taichung, with a capacity of 4,400 megawatts and annual coal use of around 13 million tons, and Hsinta, with a capacity of 2,100 megawatts and annual coal use of around 6 million tons [***10***].

Indonesia is the third largest coal producer in Asia (after China and India), but with its smaller economy and power needs, it consumes less than half as much coal as Taiwan. Political and economic instability could affect coal production and consumption in Indonesia, although the first part of 2000 was a good year in terms of production, sales, and increased domestic demand. During the summer of 2000, worker strikes for higher wages at the country's largest coal producer, Kaltim Prima (jointly owned by Rio Tinto and BP Amoco), caused the company to declare *force majeure* on export contracts and contributed to a tightened Asian market [***11***].

Elsewhere in developing Asia, Thailand uses about as much coal as Indonesia, and with a brighter economic outlook, is expecting steady growth in coal consumption. Malaysia uses far less coal, generating more power from domestically produced natural gas, although it is building and commissioning several large coal-fired power plants that will lead to rising coal use [***12***].

Industrialized Asia

Among the Asian industrialized countries—Australia, New Zealand, and Japan—Australia is the world's largest coal exporter and Japan is a major importer. Australian coal exports grew steadily in the 1990s, facilitated by aggressive pricing policies on the part of marketers. More than half of Australia's coal production is exported, with nearly one-half of it bound for Japan. Australia is also the fourth largest coal consumer in the Asian region, using coal to fuel the bulk of its power generation.

Japan, which is the third largest coal user in Asia and the fifth largest globally, imports basically all the coal it consumes, much of it from Australia. Some coal is used for the country's steel production (Japan is the world's third largest steel producer and second leading producer of pig iron), which experienced strong growth during the first part of 2000. Coal is also used heavily in the Japanese power sector, accounting for about 16 percent of the energy used for electricity generation and 45 percent of the coal used in the country. More than 3 gigawatts of coal-fired power generating capacity was reportedly added by Japanese utilities during 2000, with several new generating units ranging in size from 700 to 1,000 megawatts [***13***].

Western Europe

Coal consumption in Western Europe has declined by almost 40 percent over the past 9 years, from 894 million tons in 1990 to 546 million tons in 1999. The decrease was smaller on a Btu basis, as much of it resulted from reduced consumption of low-Btu lignite in Germany. Coal consumption is also expected to decline over the forecast period, but at a slower rate. One reason for the decline is that environmental concerns in Western Europe are particularly strong, affecting the competition among coal, natural gas, and nuclear power in the electricity sector. On the other hand, consumption could be positively affected by the planned phaseout of nuclear power in some countries [***14***]. A sustained increase in natural gas prices (which were higher during 2000) would also increase the competitiveness of coal, particularly in the power sector.

The consumption of hard coal, in particular, has been declining in Western Europe along with regional production.[11] Following the closure of the last remaining coal mines in Belgium and Portugal in the early 1990s, only four countries in the European Union—the United Kingdom, Germany, Spain, and France—continue to produce hard coal, now at declining rates [***15***]. In Germany, Spain, and France, agreements on future coal production subsidies that involve the governments, mining companies, and labor unions suggest that further production declines are forthcoming.

A pattern of declining domestic coal production and consumption is evident in the United Kingdom, the second largest coal user in Western Europe (and for many years, the largest producer). However, this trend was affected by the privatization of British Coal at the end of 1994 as well as one of Europe's most advanced deregulation programs in the gas and power industries. Production of bituminous coal in the United Kingdom declined between 1991 and 1999 by 62 million tons, and coal consumption fell by 53 million tons (45 percent) during the same period. The country's coal imports have risen steadily over the past few years and are increasingly favored for their lower prices and lower sulfur content. During 2000, AES (from the original name of Applied Energy Services) announced a switch to imported coal for its Drax power plant, and British Energy announced that it would use imported coal at the Eggborough power plant taken over from National Power [***16***].

Coal production subsidies in the United Kingdom were phased out and discontinued for several years, but during 2000 the government announced that it would resume subsidies. An aid package approved by the European Commission is designed to help UK coal mines (those that may be viable in the long run) survive the current period of low coal prices and decreased restrictions on the use of natural gas for electricity [***17***]. The subsidy package involves $167 million made available through July 2002.

In comparison to the United Kingdom, a German plan for subsidies to its coal industry was scrutinized by the European Union (EU), which had concerns that too much aid was planned for the industry's operational costs and not enough for shutting down unprofitable mines. Germany adjusted its plan by allocating more of the planned funds to mines due for closure [***18***]. As the largest consumer of coal in Western Europe, Germany accounted for 47 percent of regional consumption in 1999. Most of Germany's coal use is for power generation and district heat. Consumption declined steadily in the 1990s, as did domestic coal production (a trend similar to that in the United Kingdom). Between 1991 and 1999, German lignite production declined by 130 million tons reflecting in large part the closure of unprofitable mines [***19***]. In the *IEO2001* 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 expected to fall to 219 million tons from the 1999 level of 258 million tons, a drop of 39 million tons over a 21-year period.

France is not a large producer or consumer of coal, accounting for less than 5 percent of Western Europe's coal consumption in 1999. A plan is already well under way there to modernize, rationalize, and restructure the coal industry, with a goal of closing all mines in France by 2005. The trend in reducing production capacity partly reflects unfavorable geological conditions. French coal production has been in the decline since the 1960s [***20***], and about 22,000 jobs were lost to mine closures and industry restructuring between 1986 and 1999. Coal accounts for about 6 percent of electricity supply in France, which is predominantly from nuclear power. After the floods of early 2000, however, repair and maintenance outages at nuclear power plants led to a burst of coal imports. As a result, imports for the year are likely to be much higher than originally anticipated (in the range of 8 million tons, instead of 3 million tons) [***21***].

Spain produces and consumes more coal than France but still far less than the United Kingdom. Production of hard coal is in decline, and Spain also has a plan to restructure the industry and reduce subsidies. The process could involve a number of challenges, because Spanish coal fields generally are located in small, geographically isolated areas that are heavily dependent on coal mining [***22***]. Lower than average rainfall in Spain and Portugal during part of 2000 depleted hydropower reserves and contributed to higher than expected coal imports [***23***].

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

[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 EIA, subbituminous coal production is included in the bituminous category.

are expected to reduce coal use over the forecast period. Coal consumption in Italy is projected to remain relatively flat in the *IEO2001* forecast. Partially offsetting the expected declines in coal consumption elsewhere in Europe is a projected increase in consumption of indigenous lignite for power generation in Greece. Under an agreement reached by the countries of the European Union in June 1998, Greece committed to capping its emissions of greenhouse gases by 2010 at 25 percent above their 1990 level—a target that is much less severe than the emissions target for the European Union as a whole, which caps emissions at 8 percent below 1990 levels by 2010.

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 674 million tons since 1988, 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 *IEO2001* reference case, coal's share of total EE/FSU energy consumption is projected to decline from 22 percent in 1999 to 10 percent in 2020, and the natural gas share is projected to increase from 45 percent in 1999 to 53 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. Of the three, Kazakhstan has shown the most rapid progress. Many of Kazakhstan's 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 [***24***].

In Russia and Ukraine, efforts have been aimed primarily at shutting down inefficient mines and transferring associated support activities—such as housing, kindergartens, and health facilities—to local municipalities. The closure of inefficient mines in both countries has been slow, however, leading to delays in the scheduled disbursement of loan money from the World Bank. In addition, Ukraine lost access to funding from the International Monetary Fund (IMF) for a period of time after it provided incorrect information to IMF about its monetary reserves. In both countries, coal-mining regions continue to wield considerable political clout, putting pressure on the leadership through strikes and their ability to influence election results. In the fourth quarter of 2000, the World Bank released the final $70 million of a $300 million coal sector adjustment loan initially approved in December 1996 [***25***]. The two final segments ($150 million) of $1,300 million in coal sector adjustment loans to Russia are scheduled to be disbursed by the World Bank during the first quarter of 2001 [***26***].

In Eastern Europe, Poland is the largest producer and consumer of coal; in fact, it is the largest coal producer in Europe and second only to Germany in consumption. In 1999, coal consumption in Poland totaled 164 million tons and was dominated by hard coal use. Coal consumption in other Eastern European countries is dominated by the use of low-Btu subbituminous coal and lignite produced from local reserves.

At present, Poland's hard coal industry is operating at a loss [***27***]. 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 World Bank has approved loans to support restructuring of the coal industries in both Poland and the Czech Republic, which are continuing to close unprofitable mines.

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 1,297 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 44 percent in 2020 [***28***]. The forecast reflects projected declines (in real terms) in both minemouth coal prices and coal transportation rates, as well as heavy use of existing coal-fired power generating capacity to help meet expected growth in electricity demand.

In Canada and Mexico, coal consumption is projected to rise from 77 million tons in 1999 to 93 million tons in 2020. In the near term, Canadian cement producers faced with high natural gas prices during 2000 (in western Canada) are looking at converting to coal use [***29***]. After reaching an historical peak in 1997, Canadian coal production declined for a second consecutive year in 1999, accompanied by several mine closures and a slight drop in exports, reflecting expanded international competition (particularly from exporters in Australia, Indonesia, and China) [***30***].

Mexico consumed 13 million tons of coal in 1999. Two coal-fired generating plants 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 [***31***]. Domestic production is located predominantly in the northern state of Coahuila and includes a high proportion of low-quality brown coals (used for power generation) [***32***]. On Mexico's Pacific coast, a newly completed import facility with a throughput capacity of 10 million tons per year will supply CFE's Petacalco power plant and a nearby integrated steel mill [***33***]. Despite this activity, natural gas is expected to be the fuel of choice for most new generating capacity in Mexico.

Africa

African 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 [***34***]. Ranked third in the world in coal exports since the mid-1980s (behind Australia and the United States), South Africa became the second largest coal exporter 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 15 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 a quarter of all liquid fuels consumed in South Africa [***35***].

For Africa as a whole, coal consumption is projected to increase by 39 million tons between 1999 and 2020, primarily to meet increased demand for electricity (this forecast assumes 4.1-percent average annual economic growth for the region). 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.

In Nigeria, for example, the Ministry of Solid Minerals Development approved a coal development plan in 2000, including the reentry of Nigeria into international coal trade and increased domestic use [***36***]. 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. A large portion of the country's electricity is supplied by hydropower, which has led to shortages during recent times of drought [***37***]. Tanzania also has begun promoting plans for coal resource development (the Mchuchuma-Katewaka mine) and a new 400-megawatt coal-fired power plant to improve power supply and attract foreign investment [***38***].

Central and South America

Coal has not been an important source of energy in Central and South America, accounting for less than 5 percent of the region's total energy consumption in 1999. 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, with Colombia, Chile, Argentina, and to a lesser extent Peru accounting for much of the remaining portion. The steel industry in Brazil accounts for more than half the country's total coal consumption, relying on imports of coking coal to produce coke for use in blast furnaces [***39***]. Although Brazil's steel production was fairly flat in the late 1990s, strong growth during the first part of 2000 was part of a broader industry trend.

In the forecast, increased use of coal for making steel (both coking coal and coal for pulverized coal injection) makes up a large portion of the projected increase in Brazil's coal consumption. The expected completion of several coal-fired power plants in Brazil, fueled primarily by domestic coal, accounts for much of the remaining growth in coal consumption projected for South America. In Colombia, weakening government authority during 2000 at the hands of paramilitary and guerilla groups slowed foreign investment and domestic coal production.

In Puerto Rico, AES plans to build a 450-megawatt coal-fired plant despite the recent commissioning of a gas-fired power plant fueled by liquefied natural gas from Trinidad and Tobago. This suggests that coal could be competitive for power generation in those parts of Central America where pipeline natural gas and hydropower are not available.

Middle East

The Middle East, including Turkey, accounted for about 2 percent of global coal use in 1999. As a whole, the region relies heavily on oil and gas for its primary sources of energy. Still, coal use is expected to grow in the region. In the *IEO2001* reference case, coal consumption in the Middle East is projected to increase from 96 million tons in 1999 to 120 million tons in 2020, representing an average annual growth rate of 1.1 percent.

Turkey accounts for most of the coal that is used in the Middle East. In 1999, a total of 84 million tons of coal was consumed in Turkey, most of it low-Btu, locally produced lignite [***40***]. Over the forecast period, coal consumption in Turkey (both lignite and hard coal) is expected to increase by 17 million tons, primarily to fuel additional coal-fired power generation.

Israel and Iran accounted for most of the remaining 12 million tons of coal consumed in the Middle East in 1999. In Israel, all the coal consumed is used for power generation and district heating, and coal accounts for roughly 75 percent of the country's total electricity generation [*41*]. The startup of two new coal-fired generating units at Israel Electric Corporation's Rutenberg plant in 1999 and 2000 is expected to add approximately 3 million tons to Israel's total annual coal consumption [*42*]. Israel is now pursuing a natural gas development plan in order to diversify its fuel mix. In Iran, approximately 1 million tons of coal consumption has been met historically by indigenous suppliers [*43*].

Trade

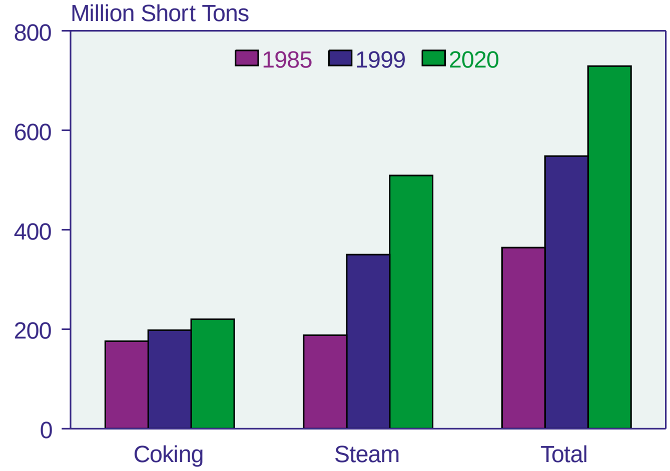
Overview

The amount of coal traded in international markets is small in comparison with total world consumption. In 1999, world imports of coal amounted to 548 million tons (Table 17 and Figure 57), representing 12 percent of total consumption. By 2020, coal imports are projected to rise to 729 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 58). Rising production costs in the indigenous coal industries in Western Europe, combined with continuing pressure to reduce industry subsidies, have led to substantial declines in production there, creating the potential for significant increases in coal imports; however, slow economic growth in recent years, 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.

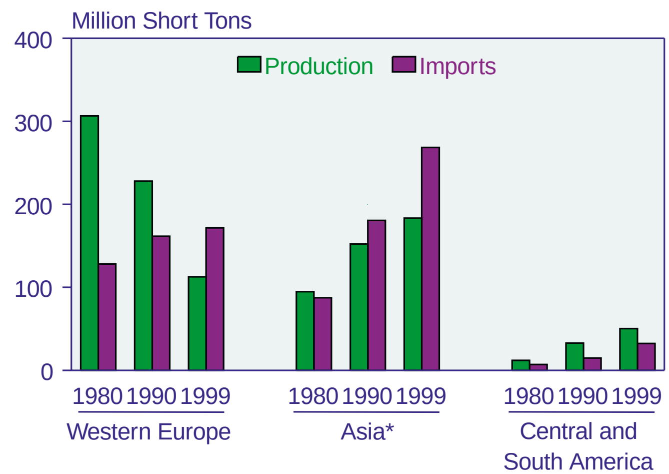
Most recently, in 1999 and 2000, international coal markets have undergone some significant changes, particularly on the supply side (coal export capacity and ocean transportation). In 1999, fierce price competition prevailed in world coal markets, substantially affecting trade patterns and the revenues obtained from exports. Australia and Indonesia saw major increases in their coal exports in 1999, while the United States saw a major reduction in its exports for the year, dropping to the lowest level since the mid-1970s [*44*]. Because of the reduction in U.S. coal exports, South Africa was able to displace the United States as the world's second largest coal-exporting country, a position that the United States had held since 1984.

Figure 57. World Coal Trade, 1985, 1999, and 2020



Sources: **1985:** Energy Information Administration (EIA), *Annual Prospects for World Coal Trade 1987*, DOE/EIA-0363(87) (Washington, DC, May 1987). **1999:** International Energy Agency, *Coal Information 1999* (Paris, France, August 2000); Energy Information Administration, *Quarterly Coal Report, October-December 1999*, DOE/EIA-0121(99/4Q) (Washington, DC, April 2000). **2020:** Energy Information Administration, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), National Energy Modeling System run AEO2001.D101600A.

Figure 58. Production and Imports of Hard Coal by Region, 1980, 1990, and 1999



*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.

Although both South African and Canadian producers priced their coal exports at very competitive prices in 1999, they did not see substantial increases in shipments over 1998. On the spot market, South African exporters consistently priced their cape size cargos of steam coal at or below $18 per ton (FOB port of exit in 1999 dollars) but still were having a difficult time competing with

Table 17. World Coal Flows by Importing and Exporting Regions, Reference Case, 1999, 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]
	1999											
Australia	12.3	76.2	1.3	**87.4**	23.3	69.7	6.7	**102.0**	35.6	145.8	8.0	**189.4**
United States	4.9	4.5	17.1	**26.5**	19.4	4.1	8.7	**32.2**	24.3	8.6	25.8	**58.6**
South Africa	49.3	19.0	1.7	**70.2**	0.9	0.8	0.8	**2.9**	50.2	19.7	2.4	**73.1**
Former Soviet Union	12.1	4.9	0.0	**17.0**	2.6	2.9	0.0	**5.5**	14.7	7.7	0.0	**22.5**
Poland	14.0	0.0	0.0	**14.0**	3.3	0.0	0.7	**3.9**	17.3	0.0	0.7	**18.0**
Canada	0.1	4.5	0.7	**5.4**	6.9	20.1	2.8	**31.9**	7.1	24.6	3.4	**37.3**
China	3.4	31.5	0.4	**33.7**	0.2	6.9	0.0	**7.2**	3.6	38.4	0.4	**40.9**
South America[e]	25.8	0.0	9.3	**38.7**	0.6	0.0	1.4	**1.8**	26.3	0.0	10.7	**40.5**
Indonesia[f]	10.7	40.3	3.2	**57.2**	1.3	8.6	0.4	**11.1**	12.0	48.9	3.6	**68.3**
Total	**132.6**	**180.9**	**33.6**	**350.1**	**58.5**	**113.0**	**21.5**	**198.3**	**191.1**	**293.8**	**55.1**	**548.4**
	2010											
Australia	10.2	121.5	0.8	**132.4**	31.8	82.0	8.0	**121.7**	42.0	203.4	8.8	**254.2**
United States	5.0	7.7	9.7	**22.4**	18.9	1.3	15.0	**35.2**	23.8	9.1	24.7	**57.6**
South Africa	49.6	28.9	4.6	**83.0**	1.0	6.1	0.0	**7.1**	50.5	35.0	4.6	**90.1**
Former Soviet Union	12.1	2.8	0.0	**14.9**	1.5	0.0	0.0	**1.5**	13.7	2.8	0.0	**16.4**
Poland	8.0	0.0	0.0	**8.0**	3.6	0.0	0.0	**3.6**	11.7	0.0	0.0	**11.7**
Canada	5.1	3.3	0.0	**8.4**	4.6	20.1	2.8	**27.4**	9.6	23.4	2.8	**35.7**
China	1.2	65.1	0.0	**66.4**	0.0	8.3	0.0	**8.3**	1.2	73.4	0.0	**74.6**
South America[e]	36.5	0.0	34.7	**71.2**	0.0	0.0	0.0	**0.0**	36.5	0.0	34.7	**71.2**
Indonesia[f]	9.0	64.5	0.0	**73.5**	0.9	4.0	0.0	**5.0**	9.9	68.6	0.0	**78.5**
Total	**136.7**	**293.8**	**49.7**	**480.2**	**62.3**	**121.7**	**25.8**	**209.8**	**198.9**	**415.5**	**75.5**	**690.0**
	2020											
Australia	6.6	129.3	0.9	**136.8**	35.8	86.3	12.2	**134.3**	42.4	215.6	13.1	**271.1**
United States	2.9	8.6	10.2	**21.7**	15.2	1.5	17.7	**34.4**	18.1	10.1	28.0	**56.1**
South Africa	46.7	38.1	4.2	**89.0**	0.0	6.6	0.0	**6.6**	46.7	44.7	4.2	**95.6**
Former Soviet Union	12.1	3.9	0.0	**16.0**	1.5	0.0	0.0	**1.5**	13.7	3.9	0.0	**17.5**
Poland	5.5	0.0	0.0	**5.5**	3.4	0.0	0.0	**3.4**	8.9	0.0	0.0	**8.9**
Canada	5.1	1.6	0.0	**6.6**	4.3	19.9	1.5	**25.7**	9.3	21.5	1.5	**32.3**
China	3.4	70.7	0.0	**74.1**	0.0	8.8	0.0	**8.8**	3.4	79.5	0.0	**82.9**
South America[e]	38.8	0.0	36.9	**75.7**	0.0	0.0	0.0	**0.0**	38.8	0.0	36.9	**75.7**
Indonesia[f]	6.8	77.0	0.0	**83.8**	0.9	4.1	0.0	**5.0**	7.7	81.1	0.0	**88.8**
Total	**127.8**	**329.1**	**52.2**	**509.1**	**61.0**	**127.3**	**31.5**	**219.8**	**188.9**	**456.4**	**83.7**	**729.0**

[a]Reported data for 1999 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 1999, total world coal flows include a balancing item used by the International Energy Agency to reconcile discrepancies between reported exports and imports. The 1999 balancing items by coal type were 3.0 million tons (steam coal), 5.4 million tons (coking coal), and 8.4 million tons (total).

[d]Includes 9.7 million tons of coal for pulverized coal injection at blast furnaces shipped to Japanese steelmakers in 1999.

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

[f]In 1999, coal exports from Indonesia include shipments from other countries not modeled for the forecast period. The 1999 non-Indonesian exports by coal type were 7.2 million tons (steam coal), 1.4 million tons (coking coal), and 8.6 million tons (total).

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

Sources: **1999:** International Energy Agency, *Coal Information 2000* (Paris, France, August 2000); Energy Information Administration, *Quarterly Coal Report, October-December 1999*, DOE/EIA-0121(99/4Q) (Washington, DC, April 2000). **Projections:** Energy Information Administration, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), National Energy Modeling System run AEO2001.D101600A.

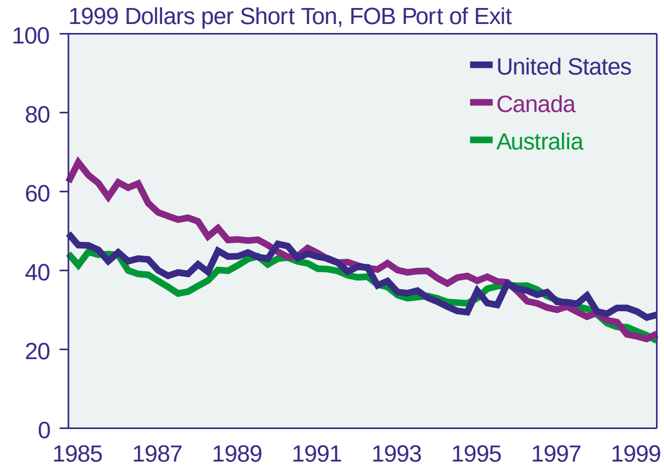
shipments of Russian and Polish coal to Europe [*45*]. Russian exporters, benefiting from a sharp decline in the ruble, were able to offer coal at a considerable discount from previous years. Canada, which relies heavily on exports of coking coal to Asian steel producers, faced a slight reduction in world coking coal demand in 1999 and strong competition from Australian producers.

A number of factors led to the 1999 drop in world coal prices, including favorable exchange rates for key exporters [*46*];[12] productivity improvements; substantial increases in coal export capacity combined with limited growth in coal imports (world coal trade increased by less than 1 percent between 1998 and 1999); aggressive price negotiations on the part of coal importers; and the acceptance of a wider range of coals (in terms of coking quality parameters) for the manufacture of coke for steelmaking. Figures 59 and 60 show FOB port-of-exit prices for steam and coking coal by quarter, as published by the International Energy Agency, in constant 1999 dollars. The figures illustrate a significant divergence in U.S. coal export prices from those of Australia and Canada since about the first quarter of 1998. Discouraged by low export prices, some U.S. coal producers idled export capacity in 1999, while others diverted some of their potential exports (both steam and coking coals) to the domestic steam coal market.

In 2000, international coal markets were affected by several factors including higher ocean freight rates, strong growth in coal import demands, a recovery in coal export prices (FOB port of exit), 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 [*47*]) and a higher delivered cost of coal imports. The short-term outlook is for shipping rates to decline to more normal levels as early as spring 2001, as a substantial amount of new shipping capacity is expected to enter the market [*48*].

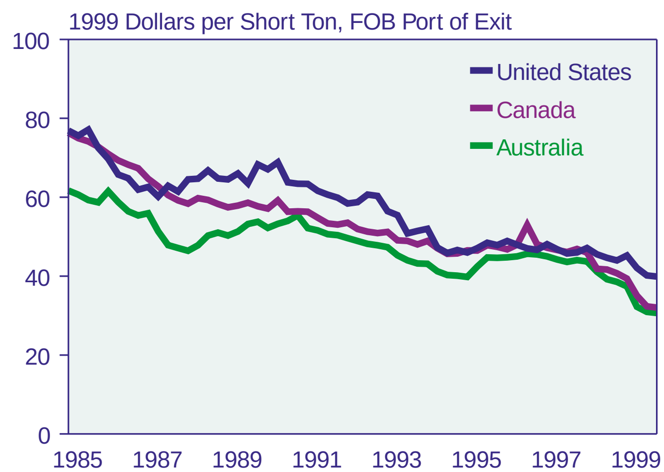
Coal export prices (FOB port of exit), the other important component of the delivered price of coal imports, leveled out in early 2000 and then increased substantially during the second half of the year. Strong growth in coal import demand and limited supplies of coal exports available to meet the additional import requirements were the key factors underlying the price recovery. For the most part, the significant growth in coal import demand in 2000 was based on the commissioning of a number of new coal-fired generating units in Asia in 1999 and 2000. An additional factor contributing to coal import growth was higher oil prices, which led to substitution of coal-fired generation for oil-fired generation in some coal-importing countries.

Figure 59. Steam Coal Export Prices by Quarter, 1985-1999



Sources: **Nominal Prices in U.S. Dollars:** International Energy Agency. **GDP Deflators:** U.S. Department of Commerce, Bureau of Economic Analysis.

Figure 60. Coking Coal Export Prices by Quarter, 1985-1999



Sources: **Nominal Prices in U.S. Dollars:** International Energy Agency. **GDP Deflators:** U.S. Department of Commerce, Bureau of Economic Analysis.

Also noteworthy was a sharp increase in coal exports from China, from 41 million tons in 1999 to more than 50 million tons in 2000. This had been a stated goal of China's Coal Industry Ministry since the mid-1990s, but

[12]The exchange rate for the Australian dollar was US$0.64 in December 1999, 20 percent below its recent historical peak of US$0.80 in May 1996. The exchange rate for the South African Rand was US$0.16 in December 1999, 41 percent below its recent historical peak of US$0.27 in January 1996. Between August 1998 and December 1999, the Russian ruble lost 75 percent of its value compared with the U.S. dollar.

one that many industry experts did not expect to be met by 2000 [***49***]. Recent actions by the Chinese government to encourage coal exports included an increase in coal export rebates and a reduction in the export handling fees charged by China's four official coal export agencies [***50***]. Australia and South Africa also were able to increase their exports of coal substantially in 2000.

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 [***51***], slightly less than its 1999 share of 27 percent [***52***]. In 1999, Japan produced 4 million tons of coal for domestic consumption and imported 147 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. Production at the two underground mines is expected to end when the government eliminates industry subsidies in 2001, leaving virtually all of Japan's coal requirements to be met by imports [***53***].

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 [***54***]. 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 [***55***].

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. To date the new pricing system has been 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 [***56***].[13] 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 the projected amount, 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. Additions to coal-fired generating capacity in these countries in 1999 and 2000 included 1,000 megawatts of new coal-fired generating capacity in Malaysia (Port Klang No. 3) and 2,040 megawatts of new coal-fired capacity in the Philippines (Sual I and II, Masinloc II, and Mauban) [***57***].

During the 1980s, Australia became the leading coal exporter in the world, primarily by meeting increased demand for steam coal in Asia. Some growth in exports of coking coal also occurred, however, as countries such as Japan began using some of Australia's semi-soft or weak coking coals in their coke oven blends. As a result, imports of hard coking coals from other countries, including the United States, were displaced. Australia's share of total world coal trade, which increased from 17 percent in 1980 to 35 percent in 1999, is projected to reach 37 percent in 2020 [***58***]. Australia should continue as the major exporter to Asia, continuing to meet approximately one-half of the region's total coal import demand.

Europe, Middle East, and Africa

Coal imports to Europe, the Middle East, and Africa taken as a whole are projected to remain relatively

[13] During Japan's fiscal year 1999 (April 1, 1999, through March 31, 2000), Australian steam coal suppliers received an average of $25.81 per ton (FOB port of exit in 1999 U.S. dollars) for coal delivered to Japan's electric utilities, 5 percent below the negotiated reference price of $27.17 per ton.

constant over the forecast period. 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 1999, the leading suppliers of imported coal to Europe were South Africa (26 percent), Australia (19 percent), South America (14 percent), and the United States (13 percent). Over the forecast period, low-cost coal from South America is projected to meet an increasing share of European coal import demand, displacing some coal from such higher cost suppliers as the United States and Poland.

The Americas

Compared with European and Asian coal markets, imports of coal to North and South America are relatively small, amounting to only 55 million tons in 1999 (Table 17). Canada imported 32 percent of the 1999 total, followed by Brazil (26 percent) and the United States (17 percent) [***59***]. Most (86 percent) of the imports to Brazil were coking coal [***60***], and a majority of the remaining import tonnage was steam coal used for pulverized coal injection at steel mills [***61***].

Over the *IEO2001* forecast period, coal imports to the Americas are projected to increase by 29 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 9 million tons in 1999 to 20 million tons by 2020 [***62***]. 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. Coal imports to the Brazilian steel industry are projected to rise substantially as the result of strong growth in domestic steel demand and a continuing switch from charcoal to coal coke. Mexico is projected to import additional quantities of coal for both electricity generation and steelmaking. Additional imports of coal to the Americas are projected to be met primarily by producers in Colombia and Venezuela.

Coking Coal

Historically, coking coal has dominated world coal trade, but its share has steadily declined, from 55 percent in 1980 to 36 percent in 1999 [***63***]. In the forecast, its share of world coal trade continues to shrink, to 30 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 the result of increased demand for steel in the developing countries. Increased imports of coking coal are projected for South Korea, Taiwan, India, Brazil, and Mexico, where expansions in blast-furnace-based steel production are expected.

Factors that contribute to the decline in coking coal imports in the industrialized countries are continuing increases in steel production from electric arc furnaces (which do not use coal coke as an input) and technological improvements at blast furnaces, including greater use of pulverized coal injection equipment and higher average injection rates per ton of hot metal produced. Each ton of pulverized coal (categorized as steam coal) used in steel production displaces approximately one ton of coking coal [***64***].[14] In 1998, the direct use of pulverized coal at blast furnaces accounted for 15 and 13 percent of the coal consumed for steelmaking in the European Union and Japan, respectively [***65***].

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[14]Approximately 1.4 tons of coking coal are required to produce 1 ton of coal coke. However, according to information provided by the World Coal Institute, each ton of coal injected to the blast furnace through pulverized coal injection (PCI) equipment displaces only about 0.6 to 0.7 tons of coal coke. As a result, each ton of PCI coal displaces approximately 1 ton of coking coal. Steel companies are able to reduce their operating costs, however, because coal used for pulverized coal injection is typically less expensive than the higher quality coals required for the manufacture of coal coke.

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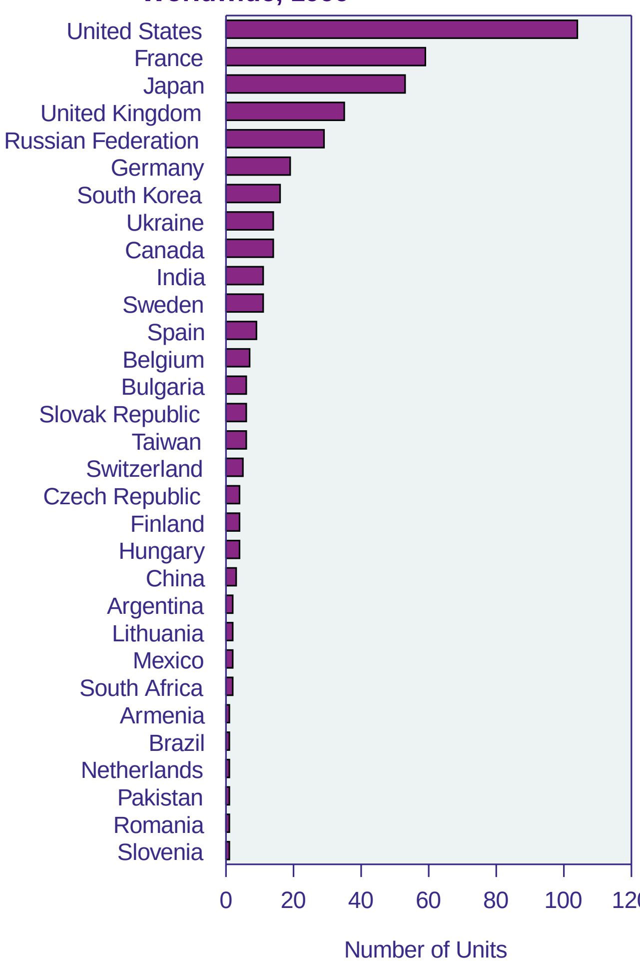
Nuclear Power

Nuclear power is projected to represent a 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.

Nuclear power plants generated electricity in 29 countries in 1999. A total of 433 nuclear power reactors were in operation (Figure 61), including 104 in the United States, 59 in France, and 53 in Japan. The largest national share of electricity from nuclear power was in France, at 75 percent (Figure 62). Belgium, Bulgaria, France, Lithuania, Slovenia, Slovakia, Sweden, Ukraine, and South Korea depended on nuclear power for at least 40 percent of their electricity generation.

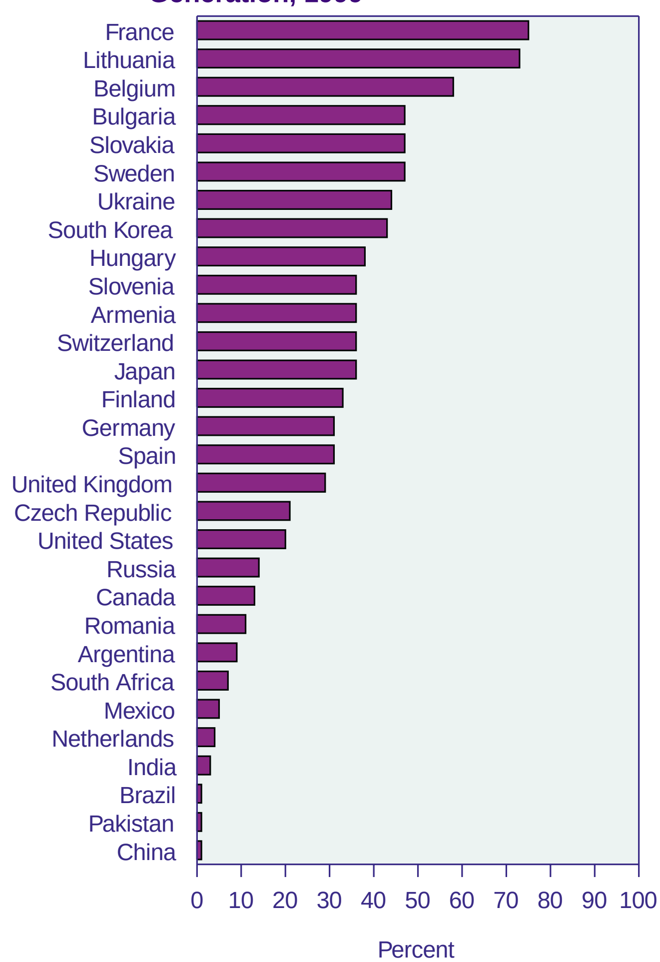
Energy from nuclear power first started to become a major source of electricity in the early 1970s, and from 1970 to 1980 world consumption of energy from nuclear power grew by about 700 percent (Figure 63). In 1979, however, the nuclear power plant accident at Three Mile Island did much to discourage further development of nuclear power in the United States. Similarly, the meltdown of the Soviet Union's Chernobyl plant in 1986 encouraged anti-nuclear public sentiment, particularly in Western Europe. Cost overruns for nuclear power plant construction projects in a number of countries also began to erode the confidence of investors. The growth in nuclear energy use worldwide slowed to about 200 percent in the 1980s, and in the 1990s it fell to roughly 20 percent.

Figure 61. Operating Nuclear Power Plants Worldwide, 1999



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

Figure 62. Nuclear Shares of National Electricity Generation, 1999



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

In the *International Energy Outlook 2001* (*IEO2001*) reference case, nuclear energy use is projected to continue a modest increase through 2010, followed by a leveling off through the remainder of the forecast to 2020. The total increase in nuclear energy consumption from 1999 to 2020 is projected to be 8 percent.

Concerns over nuclear plant safety are among the factors that have slowed the growth in world nuclear power use. In addition to the Three Mile Island and Chernobyl incidents, more recent nuclear power accidents—such as the accidental criticality event at a nuclear fuel facility in Tokaimura, Japan, in 1999—have further reduced public enthusiasm for nuclear power. Proliferation of nuclear weapons is also of concern, in that several nations have developed nuclear weapons programs as offshoots of their civilian nuclear research programs since the 1960s. Recent explosions of nuclear devices in India and Pakistan have heightened those concerns. Cost is another factor that has worked against nuclear power in some countries, particularly during years of relatively low fossil fuel prices. The high capital costs of nuclear power plant construction can discourage investment in new capacity, particularly when interest rates are high.

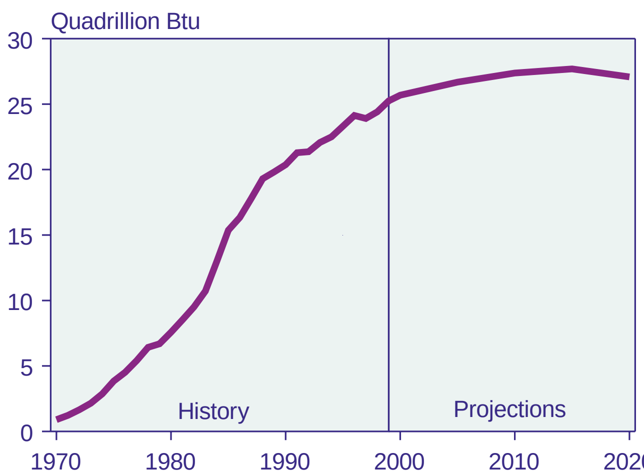
The industrialized nations accounted for about 80 percent of the world's total nuclear power capacity in 1999 (Table 18); however, the *IEO2001* reference case estimates that nuclear capacity in the industrialized nations will be 12 percent lower in 2020 than in 1999. In Western Europe, where nuclear power plants provided 35 percent of the energy used for electricity generation in 1999, a significant reduction in the nuclear share of electricity supply is expected by 2020. Finland and France in Western Europe, Japan in Asia, and Canada and Mexico in North Amercia are the only industrialized countries expected to maintain or expand their current levels of nuclear generation capacity.

Reduced reliance on nuclear energy is also expected in Eastern Europe and the former Soviet Union (the EE/FSU region), which accounted for 13 percent of the world's nuclear power generation capacity in 1999 but is projected to account for 11 percent in 2020. Many of the nuclear plants currently in operation or under construction in the EE/FSU region have been criticized as inherently unsafe according to Western operational safety practices. Several are currently slated for early retirement, and some of those currently under construction may never become operational.

In contrast to the industrialized world, the developing world is expected to more than double its nuclear generation capacity by 2020. In 1999 the developing world accounted for 8 percent of the world's nuclear electricity generation, but by 2020 it is projected to account for about 19 percent. The greatest expansion of nuclear generation capacity is expected in China, followed by South Korea and India. In 1999, 38 reactors were under construction in 14 developing countries (Figure 64), including 7 in China, 4 in South Korea, and 3 in India.

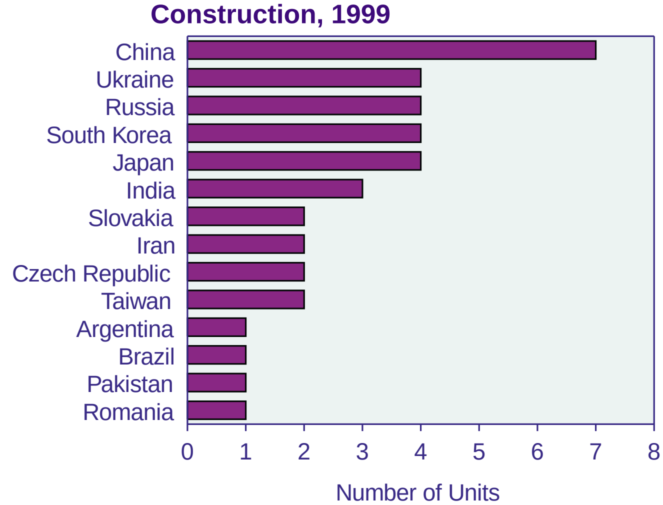
Recent events suggest that phaseouts of nuclear power could accelerate in some nations over the coming years. Belgium, Germany, the Netherlands, Sweden, and Switzerland are now officially committed to gradually shutting down their nuclear power industries [***1***]. Turkey, which until recently was expected to pursue nuclear power development, announced in 2000 that it

Figure 63. World Nuclear Energy Consumption, 1970-2020



Sources: **History:** International Atomic Energy Agency, *Nuclear Power Reactors in the World 1999* (Vienna, Austria, April 2000). **Projections:** Based on detailed assessments of country-specific nuclear power programs.

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 18. Historical and Projected Operable Nuclear Capacities by Region, 1999-2020
(Net Gigawatts)

Region	1999[a]	2005	2010	2015	2020
Reference Case					
Industrialized	**278.1**	**280.1**	**276.5**	**265.0**	**246.0**
United States	97.2	97.5	93.7	79.5	71.6
Other North America	11.3	14.1	14.9	14.9	14.9
Japan	43.7	44.5	47.6	56.6	56.6
France	63.1	64.3	64.3	64.3	63.1
United Kingdom	13.0	11.4	9.8	8.1	5.3
Other Western Europe	49.9	48.3	46.1	42.8	35.7
EE/FSU	**45.3**	**46.1**	**43.6**	**42.3**	**37.8**
Eastern Europe	10.6	11.6	10.0	10.6	10.6
Russia	19.8	21.7	21.3	17.6	13.1
Ukraine	12.1	11.2	12.1	13.1	13.1
Other FSU	2.7	1.6	0.0	1.0	1.0
Developing	**25.5**	**35.3**	**44.7**	**53.7**	**65.8**
China	2.2	5.9	9.6	11.6	18.7
South Korea	13.0	15.9	16.3	19.4	22.1
Other	10.3	13.5	18.8	22.7	25.0
Total World	**348.9**	**361.5**	**364.6**	**362.3**	**350.9**
Low Growth Case					
Industrialized	**278.1**	**272.3**	**254.4**	**207.1**	**180.8**
United States	97.2	96.8	89.9	65.6	55.3
Other North America	11.3	11.3	11.3	10.0	10.0
Japan	43.7	43.6	43.1	33.7	40.3
France	63.1	64.3	63.4	59.0	51.7
United Kingdom	13.0	11.0	8.1	4.2	1.8
Other Western Europe	49.9	45.3	38.6	34.7	21.8
EE/FSU	**45.3**	**42.2**	**36.7**	**27.9**	**14.0**
Eastern Europe	10.6	10.4	10.0	10.0	6.4
Russia	19.8	19.5	15.5	11.2	6.7
Ukraine	12.1	11.2	11.2	6.7	1.0
Other FSU	2.8	1.2	0.0	0.0	0.0
Developing	**25.5**	**31.7**	**39.4**	**44.1**	**46.0**
China	2.2	5.3	8.6	9.6	10.6
South Korea	13.0	14.9	16.2	18.5	20.2
Other	10.3	11.6	14.5	16.0	15.3
Total World	**348.9**	**346.3**	**330.5**	**279.0**	**240.9**
High Growth Case					
Industrialized	**278.1**	**284.6**	**295.1**	**301.6**	**301.7**
United States	97.2	97.5	96.9	94.3	88.5
Other North America	11.3	14.9	14.9	14.9	14.9
Japan	43.7	45.6	58.7	68.8	74.4
France	63.1	64.6	64.3	65.8	67.2
United Kingdom	13.0	12.3	11.0	10.6	11.4
Other Western Europe	49.9	49.9	49.3	47.3	45.3
EE/FSU	**45.3**	**49.2**	**49.7**	**49.1**	**55.0**
Eastern Europe	10.6	11.6	11.9	12.0	13.6
Russia	19.8	22.7	23.4	22.1	22.2
Ukraine	12.1	12.1	13.1	13.1	15.0
Other FSU	2.8	2.7	1.4	2.0	4.2
Developing	**25.5**	**38.3**	**56.1**	**73.7**	**88.7**
China	2.2	6.6	11.6	18.7	20.7
South Korea	13.0	16.8	19.7	21.4	26.2
Other	10.3	14.9	24.8	33.7	41.9
Total World	**348.9**	**372.1**	**400.9**	**424.5**	**445.3**

[a]Status as of December 31, 1999. 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 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000). **Foreign:** Based on detailed assessments of country-specific nuclear power programs.

has now put off doing so. In July 2000 Turkey's Prime Minister, Bulent Ecevit, announced the suspension of efforts to construct the nation's first nuclear power plant, the Akkuyu Bay project [***2***]. Turkey will instead rely on increased natural gas imports.

Thus far, only Sweden and Germany have committed to the early retirement of 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. However, many nations may find that viable alternatives to nuclear power are more difficult to develop than anticipated. Sweden, for instance, after committing to closure of its two Barsebäck nuclear power units by 2001, put off the closure of Barsebäck 2 in 2000.

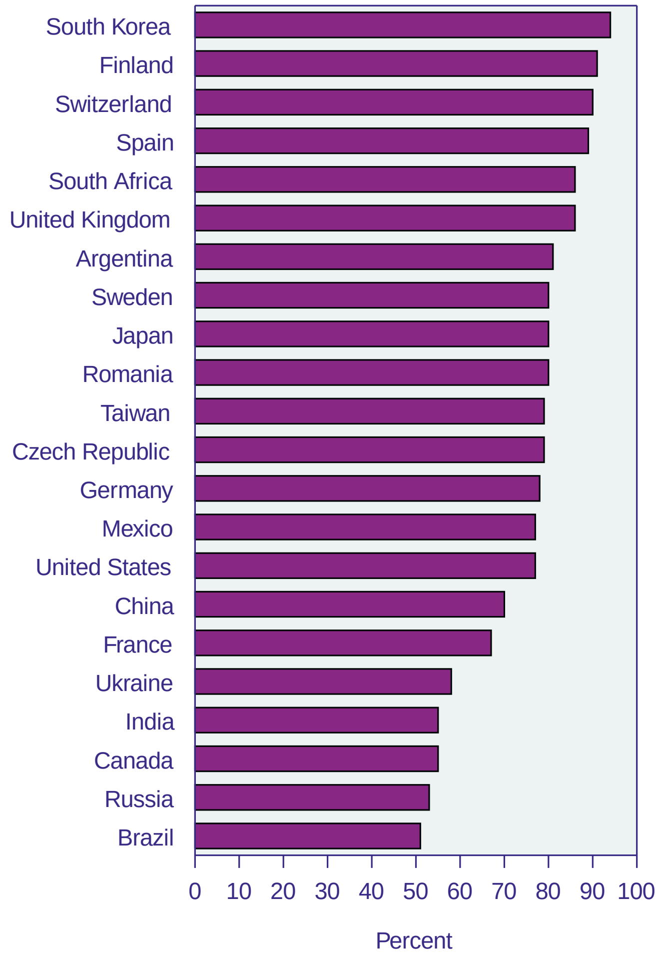
Not all recent nuclear power developments suggest a more rapidly contracting industry. In contrast to Europe, nuclear power's future in the United States may have improved slightly over the past year or two. In 2000, the industry regulator, the U.S. Nuclear Regulatory Commission (NRC), granted its first extensions to permit a company to operate two nuclear reactors 20 years beyond their initial 40-year operating licenses. Other U.S. companies have also petitioned the NRC for nuclear plant life extensions. In addition, a recent spate of mergers and acquisitions among U.S. nuclear power producing companies may improve the industry's financial health. Acquiring companies involved in recent U.S. nuclear merger and acquisition activities have often cited the prospects for future efficiency gains as a motivating factor for the industry's recent consolidation.

The late 1990s also saw the first instance of a foreign company purchasing a U.S. nuclear power unit. In December 1999, British Energy, through its AmerGen joint venture with PECO Energy of the United States, purchased the Clinton power station in Illinois [***3***]. One week after the Clinton acquisition, AmerGen announced that it intended to purchase Three Mile Island unit 1. British Energy currently owns 8 nuclear plants in the United Kingdom and has stated its intention to eventually acquire 20 nuclear power plants [***4***]. Subsequent to its joint venture with PECO, British Energy has also reached an agreement to lease and operate two of Canada's largest nuclear power plants [***5***]. Another UK company, British Nuclear Fuels Corporation, has joined with PECO Energy in a commitment to invest in South Africa's Pebble Bed Modular Reactor (PBMR) technology, which its promoters hope will do much to improve the prospects for nuclear power both in South Africa and globally (see box on page 88).

Recent improvements in operating performance may also have improved nuclear power's global prospects. The average availability factor for the world's nuclear power plants has improved from 72 percent in 1990 to 79 percent in 1998 [***6***], and the average for U.S. nuclear plants has risen from 62.2 percent in 1989 to 85.5 percent in 1999 [***7***]. Improved capacity utilization allowed the U.S. nuclear power industry to increase its net generation by 38 percent between 1989 and 1999[15] with only a 2-percent increase in U.S. nuclear capacity [***8***].

Measures of nuclear power plant efficiency in different countries vary considerably. For example, the average capacity factor for a given country's nuclear plants can vary over time as a result of scheduled maintenance outages. For 1998, national average capacity factors ranged from a high of 94 percent for South Korea to a low of 51 percent for Brazil (Figure 65).

Figure 65. National Average Nuclear Power Plant Capacity Factors, 1998



Source: Energy Information Administration, *Annual Energy Review 1999*, DOE/EIA-0384(99) (Washington, DC, July 2000), pp. 301 and 303.

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

Regional Developments

Western Europe

Currently, among European countries, only France and Finland have shown any intent to expand their nuclear power industries. In May 2000, the Finnish Minister of Trade and Industry, Sinikka Mönkäre announced that she would back a new nuclear unit [***9***], noting that an increased role for nuclear power would be the only way for Finland to meet its Kyoto Protocol carbon reduction goals. Most of the other nations of Western Europe have decided either to curtail further development of nuclear power or to abandon it entirely. Belgium, Germany, the Netherlands, Spain, Sweden, and Switzerland have recently committed to gradual phaseouts of their nuclear power programs [***10***].

The move away from nuclear power in Europe is now several decades old. Italy discontinued its nuclear energy program in 1987 after a national referendum supported the shutdown of three operating power plants and a halt to construction on a fourth. Italy's parliament had voted against expanding the country's nuclear utility industry just after the 1986 Chernobyl accident. In 1990, Italy began to dismantle its four nuclear reactors.

In a referendum held in 1978, Austria voted to ban nuclear energy entirely. In 1999, the Austrian parliament added a clause into the nation's constitution declaring Austria to be a non-nuclear country, banning the building of nuclear power plants and storage facilities. As a result of the 1978 referendum, Austria had decided not to start the operation of its one nuclear power plant. Among Western European nations, Austria is the closest to Ukraine and was most affected by the Chernobyl disaster. Austria has since opposed the further development of nuclear power in neighboring Slovakia and the Czech Republic. Czech efforts to bring its Temelin plant into commercial operation in 2001 have met with Austrian attempts to defer the Czech Republic's entry into the European Union [***11***].

In 1984, Spain's then Socialist government imposed a moratorium on the construction of new nuclear power plants [***12***]. Spain's Socialist and Communist parties have called for a shutdown of the nation's nuclear power industry. The country intends to start shutting down its nine nuclear power plants in roughly 10 years.

Sweden and Germany have also adopted 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 [***13***], 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 supposed to be closed in July 2001 [***14***], but in August 2000 the Swedish government announced that the Barsebäck 2 closure would also be delayed. After closing Barsebäck 1, Sweden replaced the lost electricity generation with imported power from coal-fired plant in Denmark, causing an increase in Western Europe's total carbon dioxide emissions.

In June 2000, Germany committed to ending its reliance on nuclear power. The plan calls for the shutdown of all Germany's reactors after they 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 phase out. The Social Democratic German Chancellor, Gerhard Schroeder, initially favored a 20-year phase out but reached a compromise with the electric utility industry [***15***]. The German government also decided to eventually stop the foreign reprocessing of its spent nuclear fuels [***16***], but that decision was rescinded in early 2001, ending a 3-year moratorium on spent fuel shipments to foreign reprocessing plants [***17***].

In 1999, Belgium's coalition government adopted a program calling for the gradual closing of the country's nuclear power plants after 40 years of operational service [***18***]. Belgium's seven nuclear reactors accounted for 60 percent of the country's net electricity generation in 1997 [***19***]. Three reactors are scheduled to be decommissioned in 2015 and the remaining four in 2025 [***20***]. The Netherlands shut down one of its two reactors in 1997, and the other is slated to be shut down in 2004.

In 1990, 4 years after the Chernobyl accident, Swiss voters elected to impose a 10-year moratorium on nuclear power plant construction. In October 2000, the Swiss government decided to extend the moratorium to 2010 but did not place time limits on the lives of currently operating units, in light of the difficulties foreseen by Swiss policymakers in finding replacement power while meeting the need to reduce carbon dioxide emissions [***21***].

In general, Western Europe's heavy reliance on nuclear power to meet its electricity needs will make it difficult for many national governments to both phase out nuclear programs and meet their commitments to reduce greenhouse gas emissions under the terms of the Kyoto Protocol. For example, 47 percent of Sweden's electricity generation capacity in 1999 and 31 percent of Germany's was nuclear [***22***].

Pebble Bed Modular Reactors: A New Lease on Life for Nuclear Power?

In 1999, pressurized water reactors (PWRs) provided roughly half of the world's total nuclear electricity generation. Other reactor types in service around the world include boiling water reactors (BWRs), and pressurized heavy water reactors (PHWRs), among others. Since 1993, South Africa's state-owned utility, Eskom, has been working to develop a new commercial nuclear power technology, the pebble bed modular reactor (PBMR). Construction of the first PBMR is expected to begin in 2003, and it is scheduled to be operational in 2005.[a] If Eskom's estimates prove to be correct, the PBMR technology could be both safer and more economical than the nuclear power plants now in operation.

The fuel in PBMRs consists of billiard-ball-sized spheres of graphite "pebbles" containing ceramic-coated uranium dioxide particles. About 400,000 pebbles are spread about the graphite-lined reactor vessel to provide the critical mass needed for a sustained nuclear reaction. Helium at a temperature of 500°C is introduced at the top of the reactor.[b] The gas then circulates over the hot fuel pebbles, which increase its temperature to 900°C. The heated gas then flows into a gas turbine, which in turn drives a generator to produce electricity. The gas exits the turbines at 600°C and then flows into a recuperator, where the gas temperature is lowered to about 140°C. The gas temperature is reduced to about 30°C by a water-cooled precooler, then repressurized and passed back through the recuperator and sent back into the reactor. The process of using high-temperature gas as the working fluid to convert heat to mechanical energy (the turbine's rotational energy) is known as a direct Brayton cycle and, characteristically, has high thermal efficiency.

Eskom has high expectations for the new technology, estimating that it will be roughly equivalent in cost to South Africa's relatively inexpensive mine-sited coal-fired plants[c] and more economical than PWR technology. Other potential advantages being promoted by Eskom include design features that could reduce concerns about plant siting, operational safety, refueling outages, nuclear waste disposal, and nuclear arms proliferation.

The PBMR modular design is expected to improve the economics of the plant over conventional nuclear plants. Each unit, about the size of a single-family dwelling, would be factory-constructed, and the total construction time from the start of on-site construction to power generation is expected to be just 24 months when the technology is in full production.[d] The first unit is expected to have a capacity of 110 megawatts, about 10 percent of the generation capacity of a conventional PWR. The plant's relatively small size means that it would not necessarily have to be used for baseload capacity. As demand increased, modules could be added incrementally, and the units could be linked in clusters.

The PBMR technology could also overcome some of the siting problems associated with conventional nuclear plants. Because they do not use water as a coolant, PBMRs would not have to be sited near a body of water, and the passive safety features, in theory, would allow them to be located close to end users. South Africa intends to build PBMRs on the nation's eastern coast, where coal resources are not available, probably at Koeberg, where its one currently operating nuclear power plant is located.

Eskom expects the PBMR technology, employing passive safety features, to be safer than conventional nuclear reactor technologies. The helium coolant, although more expensive than water, would reduce the risk of a nuclear accident and could be used at very high temperatures without causing corrosion.[e] The graphite moderator would allow for much higher operating temperatures—750°C versus 350°C for a conventional PWR—which would eliminate the possibility of a core meltdown. If the PBMR system failed, it would simply shut down.

Another expected advantage is that, in theory, a PBMR could be refueled continuously while in operation, reducing the need for refueling outages. Fresh fuel pebbles could be added to the top of the PBMR fuel bed and old pellets removed from the bottom while the reactor remained in operation. Eskom estimates that its initial PBMR plant will approach an availability rate of 90 percent[f] (as compared with the 1999 U.S. average

(continued on page 89)

[a]"PECO Invests in Eskom's Project," *Africa News Service* (August 30, 2000), p. 1.
[b]Technology Services International, web site www.pbmr.co.za/Pebble_bed_new/preface_content.htm.
[c]"Eskom's Pebble Bed Reactor Presented to Government," *Nuclear News* (May 2000), p. 39.
[d]Technology Services International, web site www.pbmr.co.za/Pebble_bed_new/preface_content.htm.
[e]S. Thomas, "Arguments on the Construction of PBMR Reactors in South Africa," web site www.earthlife.org.za/campaigns/toxics/pmbr.html.
[f]J. Kupitz and V.M. Mourogov, "The Role of Small and Medium-Sized Reactors," The Uranium Institute 23rd Annual International Symposium (1998), web site http://uilondon.org/uilondon/sym/1998/kupitz.htm.

Pebble Bed Modular Reactors: A New Lease on Life for Nuclear Power? (Continued)

of 86 percent). In addition, the significant improvement in thermal efficiency that would be achieved by using the direct Brayton cycle would allow PBMRs to use less fuel and, thus, produce less spent fuel. As a result, the nuclear waste disposal problem could be reduced.[g]

Finally, Eskom has suggested that PBMRs would reduce the risk of nuclear arms proliferation, because they use only 9 percent enriched uranium as a fuel, and the spent fuel generated would have little value as a weapons component. If, as Eskom plans, South African PBMRs become widely exported, the need to export a uranium fuel capable of being transformed into a nuclear weapon would be greatly reduced.

South Africa's PBMR technology has gained the interest of energy policymakers from abroad and of some foreign private-sector investors. Researchers from the U.S. Nuclear Regulatory Commission (NRC) and the Department of Energy recently visited South Africa to meet with Eskom's design team, and U.S. Secretary of Energy Bill Richarson stated a desire to cooperate with the South Africans.[h] One U.S.-based company, PECO Energy, has joined with British Nuclear Fuels Corporation in making financial commitments to the venture. PECO's parent company, Excelon Corporation, began discussions with the NRC in late 2000 and early 2001 about building PBMRs in the United States.

Many critics, however, contend that it is doubtful that Eskom will, in the end, build a unit that will be competitive with other electricity production technologies, particularly in a deregulated environment. Eskom has been criticized for adopting overly optimistic estimates of construction costs ($1,000 per kilowatt of capacity) and total generating costs (1.6 cents per kilowatthour, including construction, operation, maintenance, fuel, insurance, and decommissioning costs),[i] which are about those for a conventional coal-fired power plant in the United States. One reason for the low estimated costs of building a PBMR is the assumption that many of the safety features required for conventional reactors, such as a containment building, would not be needed. The need for a traditional containment structure for PBMRs has not been demonstrated, because even a total loss of the gas coolant would not produce any radioactive releases; however, critics are concerned about the proposal to build and operate any nuclear reactor without containment.

Moreover, underlying Eskom's financial assumptions is a very low discount rate of 6 percent. Given that the capital costs of a nuclear plant determine in large measure whether construction is economical, a higher discount factor could easily undermine the financial viability of PBMRs even if all the other claims for the technology were realized. If, however, Eskom meets its goal of completing the construction within 2 years, the borrowing costs for the project will be less critical. Still, the PBMR is an untested technology from a commercial standpoint, and the success of the South African demonstration project will in large measure determine its viability.

[g]S. Thomas, "Arguments on the Construction of PBMR Reactors in South Africa," web site www.earthlife.org.za/campaigns/toxics/pmbr.html.
[h]R. Smith, "U.S. Backs South African Effort To Develop Nuclear Reactor—Eskom Seeks Global Investors in Power Project—Design Said To Be Meltdown Proof," *Wall Street Journal* (June 15, 2000), p. 4.
[i]Uranium Information Center, *Nuclear Issues Briefing Paper 16* (April 2000), web site www.uic.com.au/nip16.html.

North America

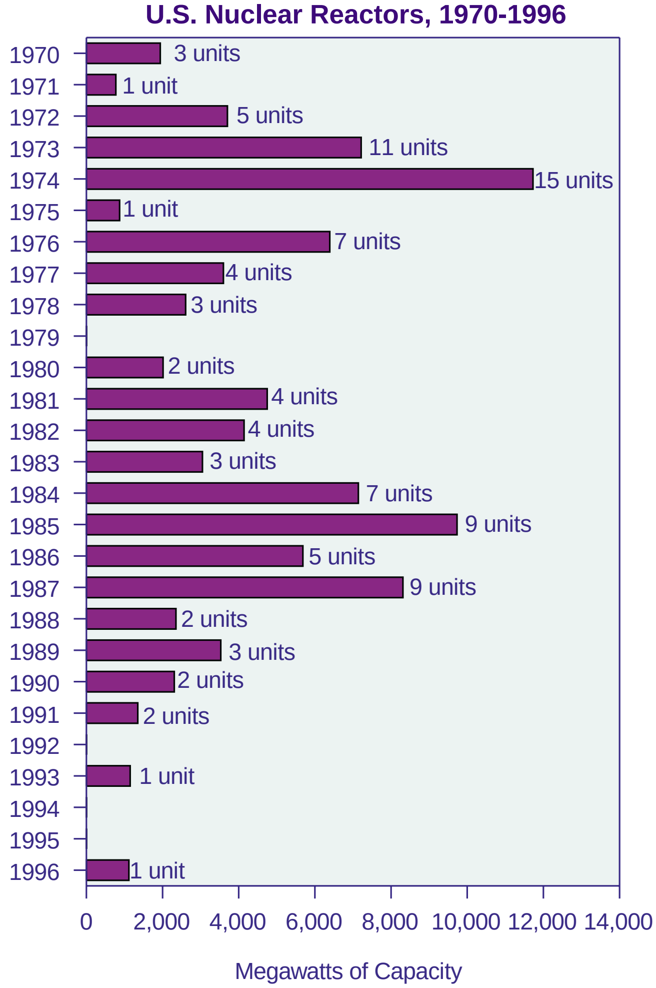
United States

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 12 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 U.S. Nuclear Regulatory Commission (NRC) for extensions of reactor operating licenses. Reductions in operating costs over the past decade have made fully depreciated nuclear plants more competitive, even as electricity markets are increasingly being deregulated.

In March 2000, Baltimore Gas & Electric (BG&E) was the first U.S. utility to receive an extension on the legal operating life of a nuclear power plant. License extensions of 20 years were granted by the NRC for BG&E's Calvert Cliffs 1 and 2 reactors, expanding their potential operating lives out to 2034 and 2036. In May 2000 the NRC granted a similar 20-year extension for Duke Energy's three-unit Oconee station beyond its original 40-year operating license [***23***]. Oconee's license was scheduled to expire in 2013, but the extension moves the end of the license periods for units 1 and 2 to 2033 and for unit 3 to 2034. In February 2000, Southern Company submitted a license renewal application for its Hatch nuclear plant, and Entergy submitted a renewal application for its Arkansas Nuclear One unit. As of January 2001, according to the NRC, license renewals were being sought for roughly 40 percent of U.S. commercial nuclear power plants [*24*].

In 2000, nearly one-third of U.S. nuclear units were 30 years old or more. No nuclear power plants are currently under construction in the United States, and there have been no new reactor orders since 1978. Construction permits for the last units built (Palo Verde 1, 2, and 3) were issued in 1976 [*25*]. Most of the nuclear power plants that came on line during the building spree of the early 1970s received 40-year operating licenses and are scheduled to be retired around 2015 (Figures 66 and 67). Given that no nuclear power plants are currently in the planning or construction stage, in large measure the industry's capacity over the 2010-2020 time frame will be determined by the extent to which the industry seeks life extensions from the NRC, the degree to which the NRC grants such extensions, and the degree to which the industry decides to use the extensions that are granted.

Figure 66. Operating Licenses Issued for U.S. Nuclear Reactors, 1970-1996

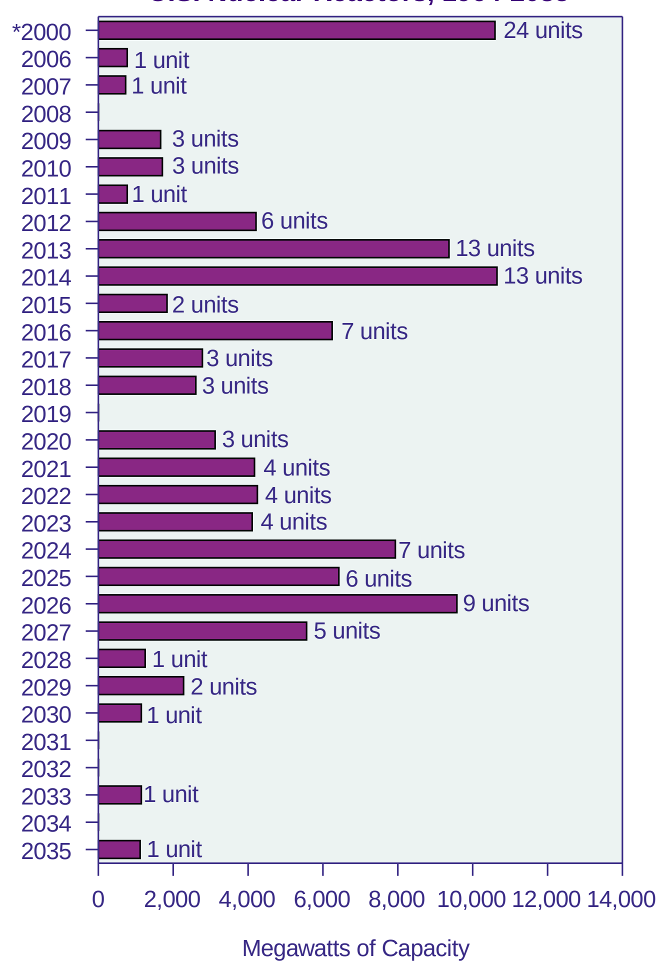


Source: U.S. Nuclear Regulatory Commission, *Information Digest 2000 Edition*, NUREG 1350, Vol. 12 (Washington, DC, June 2000), Appendix A, pp. 97-110.

Although the pursuit of a license renewal is not an insignificant undertaking (estimated at between $10 million and $20 million per reactor [*26*]), the fact that a utility may seek and receive a renewal for a nuclear power plant is not a guarantee that the life extension will be used. There is no guarantee, for example, that the economics of nuclear power relative to other sources of energy will remain stable or improve in the future. In comparison with the cost of decommissioning a nuclear unit, however, a license renewal is relatively inexpensive, and therefore some companies may choose to pursue the potential opportunity that a license renewal confers. Obtaining an extension does not require a company to undertake the capital expenditures needed to keep the unit running, which would be far greater than the cost of obtaining the license.

Since 1997, a wave of consolidation has occurred in the U.S. commercial nuclear power industry through

Figure 67. Operating License Expiration Dates for U.S. Nuclear Reactors, 1964-2035



*From 1964 through 2000

Source: U.S. Nuclear Regulatory Commission, *Information Digest 2000 Edition*, NUREG 1350, Vol. 12 (Washington, DC, June 2000), Appendix A, pp. 97-110.; and S.R. Hatcher, "Global Development of Nuclear Power," *Nuclear News*, Vol. 43, No. 3 (March 2000), p. 57.

transactions that have included company mergers and acquisitions, purchases of individual nuclear generation assets, combining the operational activities of nuclear plants owned by different companies, and sales of minority ownership shares back to majority owners. The first merger occurred in 1997, when PECO Energy Company and British Energy formed a joint partnership, AmerGen, for the express purpose of buying nuclear power plants. AmerGen has purchased five nuclear power plants to date and has plans to purchase as many as 20 plants in total. AmerGen was involved in the first purchase of a U.S. nuclear plant in its entirety in December 1999, when it bought the Clinton plant.

AmerGen and a handful of other companies are emerging as major holders of U.S. nuclear assets. Entergy, for example, has announced plans to spend $1.7 billion over 5 years to build a portfolio of 12 to 15 nuclear power units, and Duke Energy, Constellation Energy Group, and Northern States Power have also indicated interest in acquiring nuclear units [***27***, ***28***]. In addition, PECO and Entergy are involved in two of the largest mergers in the history of the U.S. nuclear power industry. Unicom and PECO completed a merger in October 2000 that created the Nation's largest nuclear utility. The combined company, Exelon, owns 17 percent of the Nation's total nuclear generation capacity, with annual revenues of $12 billion.

The largest merger on record among U.S. utilities, involving the FPL Group of Florida and Entergy Corporation of Louisiana, also involved the second largest consolidation of U.S. nuclear assets. The combined debt and equity value of the merging companies is $27 billion, and the value of the merger is estimated at $13.9 billion. The combined company will own 11 percent of U.S. nuclear generation capacity and will be the largest utility in the United States. If all the mergers currently pending are completed, the five largest owners of U.S. nuclear capacity will account for 40 percent of privately held U.S. nuclear capacity, with 100 or more owners accounting for the remaining 60 percent.

One of several factors underlying the current move toward consolidation of the U.S. nuclear industry is regulatory. The regulatory agencies that must approve electric industry mergers and acquisitions have been more inclined to do so in recent years. In addition, as deregulation proceeds, utility companies have been encouraged by State regulators either to become solely generation companies or, alternatively, to become solely distribution companies by shedding their generation assets whether nuclear or non-nuclear [***29***]. For example, the State of Massachusetts has encouraged companies to move toward vertical disintegration in order to open up the State's wholesale electricity market to competition, and favorable stranded cost recovery decisions by State public utility commissions may have encouraged similar actions in other States.

From a company perspective, operating several nuclear units may allow for greater economies of scale and more favorable procurement options. Another attraction for potential buyers of nuclear assets has been their relatively low price. In some cases, the selling price of nuclear plants has actually been negative, taking into account that the price has sometimes exceeded the value of the nuclear decommissioning fund transferred from seller to buyer. This was particularly true for some of the earliest unit sales.

By one measure, whereas thermal generation capacity in the United States has sold for two times book value, or roughly $350 per kilowatt, most of the earlier nuclear capacity sales have gone for about $80 per kilowatt [***30***]. Some of the earlier purchases of nuclear assets were made for a small fraction of book value. For instance, on November 19, 1998, Boston Edison Corporation (BEC) reached an agreement with Entergy to sell its Pilgrim nuclear plant. The selling price was $121 million. Entergy agreed to pay BEC an additional $80 million for plant and fuel, $10 million for additional fuel at closing, and $31 million for nuclear fuel credits [***31***]. The book value of the plant was $700 million [***32***]. The deal also called for BEC to turn over to Entergy a $466 million decommissioning fund.

In another early sale, AmerGen purchased the Clinton nuclear plant for $200 million, even though it cost Illinois Power $4.25 billion to build it. In the Clinton sale, AmerGen assumed full responsibility for the decommissioning. Illinois Power ceded $98 million in decommissioning funds to AmerGen and is committed to transfer additional funds sufficient to fully fund the eventual decommissioning of the Clinton reactor.

More recently, however, prices for nuclear power assets have risen markedly. For instance, in February 2000, Entergy agreed to pay the New York Power Authority $967 million for Indian Point 3 and Fitzpatrick, a record high for nuclear sales to that date [***33***]. Dominion Resources competed in the bidding process with Entergy.

In August 2000, Dominion Resources bid a record $1.3 billion for the three Millstone units owned by Northeast Utilities (including the closed Millstone unit 1), or roughly $591 per kilowatt of installed capacity [***34***]. Dominion paid $1.2 billion for the plant and related facilities along with $105 million for fuel, purchasing units 1 and 2 in their entirety and 93 percent of unit 3. In December 2000, Constellation Energy Group announced that it was purchasing Nine Mile Island unit 1 and 82 percent of Nine Mile Unit 2, a total of 1,550 megawatts of capacity, for $950 million or $613 per kilowatt [***35***]. The higher prices paid for nuclear assets in those recent sales may reflect not only the quality of the assets sold but also an improved environment for nuclear power in the United States.

Canada

Canada's nuclear electricity generation is projected to increase by 1.7 percent per year between 1999 and 2020. 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 [***36***], 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 [***37***].

Mexico

Mexico's two reactors, which became operational in 1995, took 20 years to build. Mexico is not expected to add to its nuclear capacity over the forecast period. Laguna Verde has been under criticism for unsafe operating practices in recent years. In 2000, the World Association of Nuclear Operators criticized Laguna Verde's "security procedures, radiation monitoring techniques, engineering practices, and safety culture" [***38***].

Japan

On September 30, 1999, Japan's worst nuclear accident occurred when workers at a nuclear facility in Tokaimura set off an uncontrolled nuclear reaction that resulted in the death of three workers from radiation exposure [***39***]. Nevertheless, Japan is expected to extend the operating lives of several of its nuclear power plants, The Japanese government and electricity industry also remain committed to building new commercial power reactors in the future [***40***], despite growing public concern about the operational safety of the nation's atomic power industry.

Although it is possible that public opposition to nuclear power in Japan could intensify in the future and perhaps undo the national commitment to expand nuclear generating capacity, the *IEO2001* reference case projects an increase in the nuclear share of Japan's total electricity generation, from 33 percent in 1999 to 38 percent in 2020.

Eastern European and the Former Soviet Union

Since the early 1990s, in order to allay concerns over the operation of nuclear reactors in a number of Eastern European nations, nearly $2 billion has been provided by Group of Seven nations[16] for safety measures designed to reduce the likelihood of a nuclear accident. A major goal of the effort has been to shut down the least safe nuclear reactors operating in Eastern European nations and the former Soviet Union [***41***]. The EE/FSU region has 59 reactors operating at 18 nuclear energy sites. Twenty-five are considered by the donor countries to be operating at standards below those acceptable in the West. The Western nations have set no deadlines for the shutdown of the high-risk reactors, and only two—Chernobyl units 1 and 3—have been deactivated to date.

In 1992, the International Atomic Energy Agency began a review of safety practices at Soviet-designed RBMK-type reactors. Six of the 15 RBMK plants currently in operation are "first generation" because they were built in the early to mid-1970s [***42***]. 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.

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 nuclear power plant before 2005. Similar efforts are being undertaken to close down Bulgaria's Kozloduy plants and Slovakia's Bohunice plants [***43***]. Bulgaria intends to close Kozloduy units 1 and 2 in 2002 or 2003 [***44***]. 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 [***45***], and in February 2001 Westinghouse announced that it will modernize Kozloduy units 5 and 6 [***46***]. Both Lithuania's and Slovakia's future entry into the EU has been jeopardized by the concerns associated with their nuclear power industries [***47***].

In December 1995, the Group of Seven and Ukraine reached an agreement to shut down all units at Chernobyl by 2000 [***48***]. 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.

South America

Among South American nations, only Argentina and Brazil operate nuclear power plants. Brazil's 626-megawatt Angra 1 began commercial operation in 1985,

[16] United States, France, United Kingdom, Germany, Italy, Canada, and Japan.

and the 1,245-megawatt Agra 2 began operation in July 2000. Construction of Angra 2 began in 1981 [***49***]. Not only did it come close to setting a record for the longest construction time of any nuclear power plant in the world, its estimated $9 billion cost was nearly $8 billion more than anticipated price tag of $1.3 billion when the project began [***50***]. Angra 3, Brazil's one nuclear power plant under construction, is expected to be brought into service in 2006 [***51***], but the decision to complete Angra 3 unit is pending, based on the performance of Angra 2. Brazil is expected to increase its nuclear capacity over the forecast period, and in 2020, nuclear power is expected to account for roughly 5 percent of Brazil's electricity generation.

Argentina, the other South American country with nuclear power, has also experienced difficulties in developing a nuclear power industry. Since the mid-1990s, Argentina has been attempting to privatize its Atucha 1, Atucha 2, and Embalse units. The Argentine senate passed a bill authorizing the packaged privatization of the three nuclear units in April 1997 [***52***]. The original intent was to raise funds for the completion of Atucha 2 [***53***], which was completed in 1999. At present, none of the plants has been privatized, even though the Argentine government has indicated a willingness to sell the units at a small fraction of the construction costs and to allow foreign investors to bid on the plants. Currently, nuclear power is responsible for about 9 percent of electricity generated in Argentina [***54***].

In 1983, Cuba began construction of two nuclear units (Juragua 1 and 2) with a total of 834 megawatts of capacity. Work on both units stopped in 1992, shortly after the collapse of the Soviet Union [***55***], and in 1998 Cuban President Fidel Castro announced that construction of the two units would be put off indefinitely. In December 2000, Cuba finally abandoned plans to complete Juragua 1 and 2.

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 *IEO2001* 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 1.6 quadrillion Btu in 1999 to 4.6 quadrillion Btu 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 17 percent of the world's nuclear power capacity, up from 6 percent in 1999.

China

China has ambitious plans to develop nuclear power as a source of energy for electricity generation. In 1997, the government-sponsored *China Daily* stated that China would spend $60 billion to $100 billion over the next 25 years to construct nuclear power plants [***56***]. China had three nuclear power plants in operation in 1999, and by 2020 6 percent of its electricity is projected to come from nuclear power plants, up from 2 percent in 1999.

South Korea and Taiwan

South Korea has the largest nuclear power industry among the developing Asian nations, producing 97.9 billion kilowatthours of nuclear electricity in 1999. From 1999 to 2020, generation from its nuclear power plants is expected to rise slightly in absolute terms but remain steady at about 40 percent of total electricity use. Currently, South Korea has 16 units in operation and 4 units under construction.

Taiwan is the second largest producer of nuclear electricity among the developing Asian nations, at 36.9 billion kilowatthours and 26 percent of its total electricity generation in 1999. Taiwan had three two-unit plants in operation in 1999, with a total 4,884 megawatts of capacity [***57***]. A fourth two-unit plant, Lungmen 1 and 2, is under construction, and the 1,300-megawatt units are expected to be operational in 2004 and 2005 [***58***]. In October 2000 Taiwan's Premier, Chang Chun-hsiung, announced that the project would be canceled, but Taiwan's highest court ruled in January 2001 that the government's decision was unconstitutional because the president had acted without approval from the legislature [***59***].

India and Pakistan

India launched its nuclear power research program in 1954, the first in the developing world [***60***]. India had 11 nuclear power plants in operation in 1999 and 3 under construction. Operational difficulties have hampered the performance of the operating reactors, however. In addition, the government has refused to grant entry to the International Atomic Energy Agency to conduct safety tests of India's nuclear power facilities [***61***].

As a part of its Vision 2020 plan, the Nuclear Power Corporation of India has set a goal of producing 20,000 megawatthours of electricity from nuclear power by 2020. In 1999, India relied on nuclear power for more than 2 percent of its electric power needs. The *IEO2001* reference case projects that the nuclear share of India's electricity generation will rise to almost 6 percent by 2020.

Pakistan has one operating nuclear power plant with 125 megawatts of capacity [*62*]. Another plant was activated in May 2000, and when connected to the grid it will add 300 megawatts of capacity to Pakistan's nuclear power industry.

Middle East

In July 2000 Turkey's Prime Minister announced that it would no longer proceed with its efforts to construct a nuclear power plant [*63*]. The Turkish government had previously announced plans to build 10 nuclear reactors by 2020. The first plant, at Akkuyu Bay, was to be sited on Turkey's environmentally sensitive Mediterranean coast. Turkey will instead rely on natural gas imports.

With the assistance of Germany, Iran embarked on the construction of its nuclear power plant at Beshehr in 1974. Progress on the plant was discontinued during the Iranian Revolution in 1979, and a major portion of the facility was later destroyed by Iraqi bombs during the Iran-Iraq war. In 1995, Russia emerged as sponsor and developer of the plant. Construction progress at Beshehr has proceeded slowly since, however, and it is uncertain when the plant will become operational.

Africa

Among African nations, South Africa is currently the only nation 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 has proposed the construction of a 110-megawatt demonstration reactor beginning in mid-2001 [*64*]. Both PECO Energy of the United States and British Energy have acquired ownership shares in the Eskom project [*65*] (see box on page 88).

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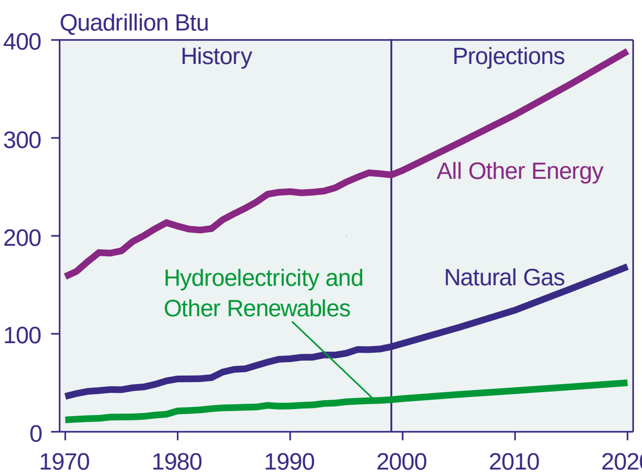
Hydroelectricity and Other Renewable Resources

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.

Although fossil fuel prices reached 10-year highs in 2000, the *IEO2001* reference case projection expects energy prices over the long term to remain relatively low, constraining the expansion of hydroelectricity and other renewable resources over the projection period. Worldwide, renewable energy use is expected to increase by 53 percent between 1999 and 2020, but the current 9-percent share of renewables in total energy consumption is projected to decline slightly, to 8 percent in 2020 (Figure 68). Total renewable energy use is projected to rise from 33 quadrillion Btu in 1999 to 50 quadrillion Btu in 2020 (see Appendix A, Table A8).

Much of the growth in renewable energy use in the *IEO2001* reference case is attributable to large-scale hydroelectric projects in the developing world, particularly in developing Asia, where China and India, as well as other developing Asian nations such as Nepal and Malaysia, are already building or planning to build hydroelectric projects that exceed 1,000 megawatts. Hydroelectricity and other renewable energy consumption is expected to grow by 4.0 percent per year in developing Asia over the projection period, with particularly strong growth projected for China (Figure 69).

Figure 68. World Consumption of Renewable Energy, Natural Gas, and Other Energy, 1970-2020

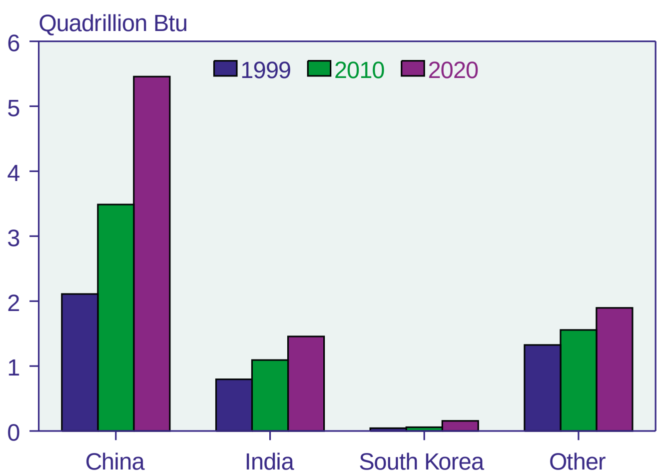


Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, World Energy Projection System (2001).

Several large-scale hydropower projects were revived or moved forward in 2000 in developing Asia. Construction of the 18,200-megawatt Three Gorges Dam project in China continued despite charges of corruption that surfaced in 2000, including a charge of embezzlement of $1.4 million by an official who was subsequently found guilty and sentenced to death [***1***]. In India, the Supreme Court ruled that construction of the 1,450-megawatt Sadar Sarovar hydroelectric project could continue after being stalled by lawsuits for more than 6 years. In Malaysia, the government announced that it was considering increasing the capacity of its Bakun hydroelectric project from 500 megawatts to 2,500 megawatts, the scale of the original plans for Bakun. Laos signed a Memorandum of Understanding with Thailand for a 25-year power purchase agreement to take electricity from the proposed 920-megawatt Nam Theun 2 project [***2***].

Among the countries of the industrialized world, wind-powered electricity is still enjoying robust growth. Several States in the United States have adopted renewable portfolio standards (RPS) that should help promote strong growth of wind power. Australia is also poised to enact legislation that will act as an RPS, and the country is already seeing a jump in the plans to install wind

Figure 69. 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, January 2001). **2010 and 2020:** EIA, World Energy Projection System (2001).

power, in excess of 1,000 megawatts [***3***]. Several countries in Western Europe continue strong development of wind power, including Germany, Denmark, and Spain. In the first 9 months of 2000 alone, 987 megawatts of wind capacity were installed in Germany, bringing the country's total wind capacity to 5,432 megawatts, twice that of the United States [***4***].

Renewable energy in Western Europe has been encouraged by a number of government policies and subsidies aimed at increasing the penetration of alternative energy sources. In 2000, the European Union (EU) Secretaries of Energy announced a cooperative position on renewables. By 2010, the EU expects renewable energy sources to contribute 22 percent of all power production among the member countries [***5***]. There are already policies in place in Germany, Denmark, and the United Kingdom to subsidize the use of renewable energy sources.

The *IEO2001* 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 most widely used form of renewable energy in North America, particularly in the United States and Canada. North America has a total of 175 million kilowatts of installed hydroelectric capacity, compared with installed capacity of 19 million kilowatts for other renewable energy sources (i.e., geothermal, wind, solar, and biomass). While Canada still has several projects planned or under construction for further expanding its hydroelectric resource base, hydropower generation in the United States is, overall, expected to decline—both because most of the best sites for hydro development have already been exploited and because of the recent emphasis on the adverse impact that large-scale hydroelectric facilities may have on the environment. In Mexico, there are few plans to expand the use of renewable energy resources beyond off-grid, small facilities in rural areas that are far from the national electricity grid. *IEO2001* projects that North America's renewable energy use will increase by 1.3 percent per year, from 11.1 quadrillion Btu in 1999 to 14.5 quadrillion Btu in 2020 (Figure 70).

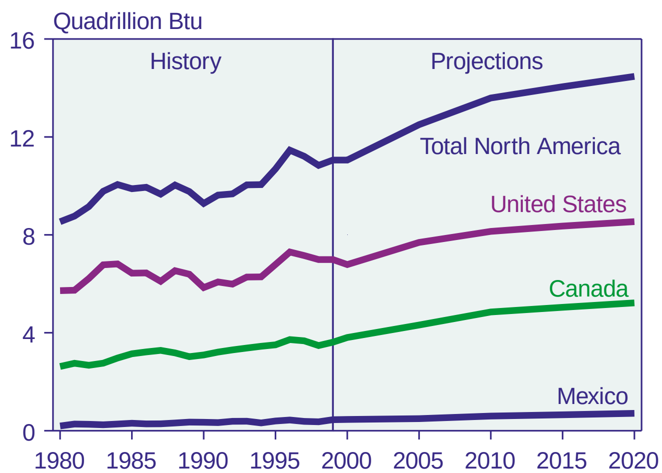
United States

Potential sites for hydroelectric power 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. The Energy Information Administration's *Annual Energy Outlook 2001* projects that conventional hydroelectric generation will decline from 389 billion kilowatthours in 1999 to 298 billion kilowatthours in 2020 as increasing environmental and other competing needs reduce the productivity of generation from existing hydroelectric capacity [***6***]. On the other hand, growth in U.S. electricity generation from other renewable energy sources (geothermal, biomass, landfill gas, and wind) is projected over the forecast horizon, from 77 billion kilowatthours in 1999 to 146 billion kilowatthours in 2020. Biomass is projected to enjoy the largest increase among renewable energy sources, rising by 80 percent and reaching 65.7 billion kilowatthours in 2020.

Ten States (Arizona, Connecticut, Maine, Massachusetts, Nevada, New Jersey, New Mexico, Pennsylvania, Texas, and Wisconsin) have introduced RPS programs, as well as other requirements to construct new renewable-powered capacity. The RPS programs vary substantially, but all require that the State's renewable share of total electricity be increased by using a range of eligible renewable sources. Much of the expected growth in renewable energy in the United States is attributed to these programs.

Texas and New Jersey account for the largest amount of new renewable electricity generating capacity expected to result from RPS programs over the forecast horizon.

Figure 70. Renewable Energy Consumption in North America, 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, January 2001). **Projections:** EIA, World Energy Projection System (2001).

The Texas RPS requires that 2,000 megawatts of new renewable energy generating capacity be constructed in Texas by 2009, with increasing interim requirements and individual utilities' shares assigned in proportion to their retail sales. The utilities may either generate the renewable electricity themselves or purchase credits from other generators with surplus renewable electricity supplies. Wind and landfill gas are expected to provide most of the renewable energy under the Texas RPS, but the selection of possible sources of renewable energy for the Texas plan also includes biomass, geothermal, hydroelectricity, and solar energy technologies. Several large wind facilities have already been announced or contracted since the program was announced.

Under New Jersey's RPS program, sales of renewable-generated electricity must increase until 6.5 percent of each of the State's retail electricity providers' sales are supplied by renewables by 2012 [***7***]. Any electricity provider falling below the renewable requirement would be required either to make it up in the next year or to purchase credits from another electricity provider with a surplus of renewable-generated electricity. There is also a provision for generating units outside New Jersey to contribute to the renewable share. Biomass and landfill gas projects are expected to account for the largest number of new renewable projects, along with some new wind power projects.

Although California does not have an RPS program, the State has enacted a renewable energy mandate with a funding requirement under California Assembly Bill 1890 (A.B. 1890). Under A.B. 1890, $162 million is to be collected from the ratepayers of investor-owned utilities. Renewable energy projects are proposed on a voluntary basis and bid for support on a per-kilowatthour incentive basis. A.B. 1890 projects are expected to include primarily wind, geothermal, and landfill gas. Although details have not yet been made available, the A.B. 1890 mandate was extended in August 2000 with additional funding.

Wind power in the United States enjoyed substantial growth in 1999, mostly because of the threatened expiration of the Federal tax credit for wind production in June 1999 (which has since been extended to the end of 2001). Between 1998 and 1999, installed wind capacity grew from 1,890 megawatts to 2,455 megawatts, with the greatest rate of construction occurring during the period from July 1998 to July 1999 [***8***], when a record 1,014 megawatts of new wind installations came on line, including 841 megawatts of new generating capacity and 173 megawatts of repowering projects (where new turbines replaced older, less efficient units, mostly in California).

New wind power projects were constructed mainly in the country's Midwest. In 1999, new wind facilities were installed in Alaska, California, Colorado, Iowa, Kansas, Maine, Minnesota, Nebraska, New Mexico, Pennsylvania, Texas, Wisconsin, and Wyoming, and wind power is now being generated in 22 States (Figure 71). In September 1999, the world's largest wind farm was dedicated near Storm Lake, Iowa. The farm, operated and owned by Enron Wind Corporation, is composed of 257 turbines with a combined capacity of 193 megawatts and will generate enough electricity for 71,000 U.S. homes [***9***]. In September 2000, New York completed the largest wind project on the East Coast, the 11.5-megawatt Madison County project near Hamilton [***10***].

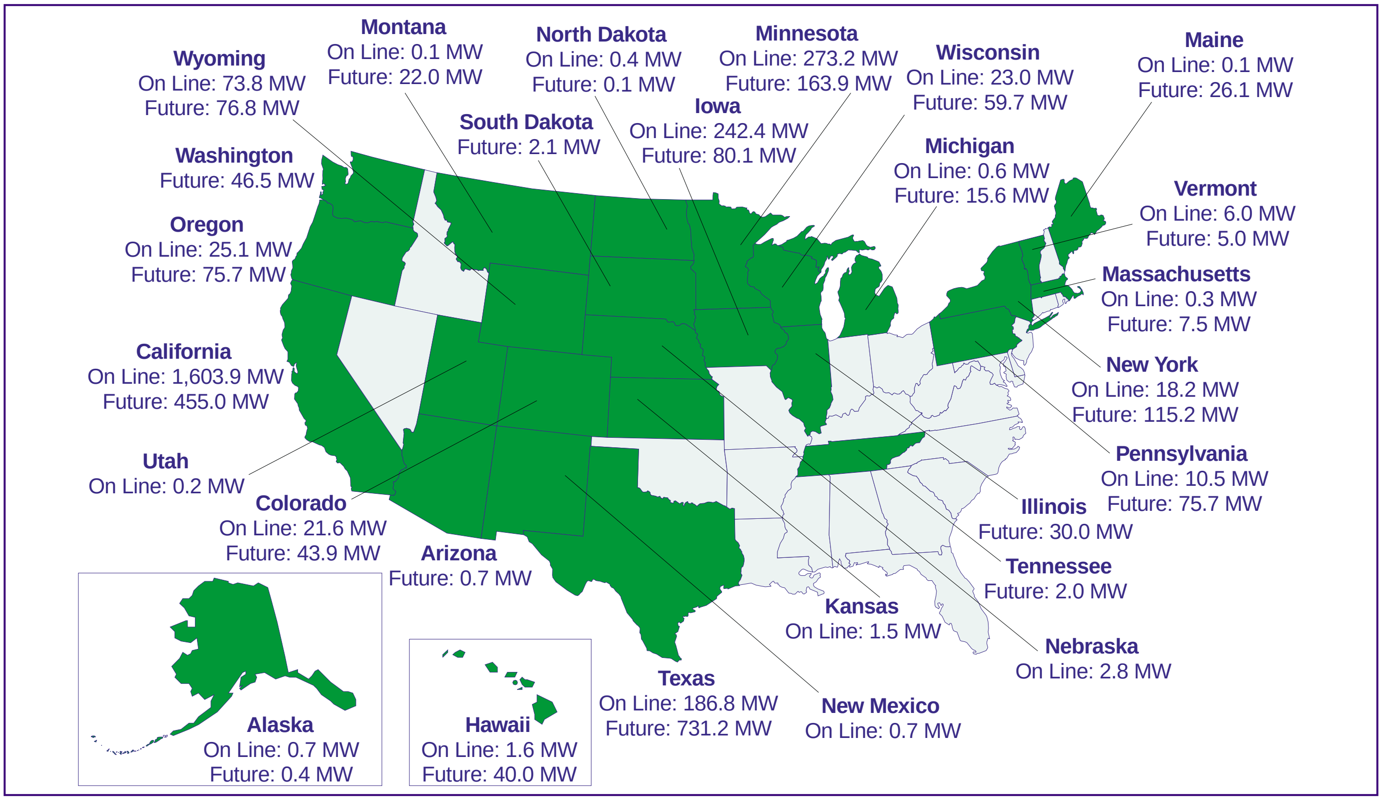
Canada

Canada has also begun modest development of its wind resources. In June, wind turbine manufacturer Vision Quest installed the largest turbines to date and connected them to the Alberta provincial grid [***11***]. The turbines, 154 feet in diameter and 164 feet high, have a peak capacity of 660 kilowatts. One is located near Pincher Creek and one near Hill Spring, both in Alberta. In December 2000, Vision Quest commissioned a 10.5-megawatt, 16-turbine wind farm at Castle River, also in Alberta province [***12***]. At present, Vision Quest has 7 wind power plants operating and 13 under construction.

In addition, the Canadian government announced that it would invest up to $329 million between 2000 and 2005 to reduce greenhouse gas emissions, with a commitment to purchase 20 percent of the government's electricity supplies from nonhydroelectric renewable resources [***13***]. To that end, the government has pledged that, by 2002, half of the average 25,000 megawatts of electric power used annually by government-owned and operated facilities in Saskatchewan will be supplied by wind. To accomplish this, the Canadian government will contribute $8.16 million over a 10-year period to Saskatchewan's electric utility, SaskPower, for the purpose of developing "green power" in the province. At present, the government is trying to negotiate a similar arrangement for Prince Edward's Island.

Canada has plans to continue developing hydroelectric sites, but for the most part the plans do not include large-scale projects that often lead to contention between developers and native populations and criticisms about their potential adverse environmental impact. Moreover, hydropower developers are trying to work more closely with native peoples to make it easier to begin construction on new projects. Hydro Quebec struck an arrangement with the Grand Council of the Crees that will allow the tribe to conduct a 3-month study of the utility's plan to develop one of the few remaining large-scale projects, the 1,280-megawatt Rupert-Eastmain Hydroelectric Project, in northern Quebec [***14***]. The utility has agreed to pay the Cree $302,800 to study the economic, commercial, and

Figure 71. Grid-Connected Wind Power Plants in the United States as of November 2000



Source: American Wind Energy Association, "Wind Project Database: Wind Energy Projects Throughout the United States," web site www.awea.org (November 15, 2000).

environmental impacts of the proposed dam. Hydro Quebec has additionally offered the Cree an opportunity to invest and become co-owners in the Rupert-Eastmain Project which would cost between $1.7 and $2.0 billion to construct and would generate revenues between $101 and $121 million each year. The project would be built on the Eastmain River (north of Nemaska) and would require diverting 90 percent of the Rupert River's flow into a planned 240-square-mile reservoir.

Similar to the Hydro Quebec/Cree agreement, Manitoba Hydro and the Tataskweyak Cree Nation reached an agreement that will give the Tataskweyak Cree partial ownership in the proposed 560-megawatt Gull Rapids hydroelectric project [***15***]. According to the agreement, the Tataskweyak Cree would be able to purchase up to 25 percent ownership in the $871 million Gull Rapids Project and would receive 25 percent of all revenues produced by the project. Gull Rapids is slated for completion in 2008. It will be located on the Nelson River near Split Lake. Manitoba Hydro also is considering development of the 150-megawatt Notigi and 250-megawatt Wuskwatim projects on the Burntwood River.

Several additional hydroelectric projects are expected to be developed in Canada. Brascan Corporation plans to construct the 90-megawatt High Falls Power Project on the Michipicoten River near Wawa in northern Ontario, Canada [***16***]. The project will cost an estimated $50 million to construct. No schedule for construction has been released. The Churchill River Project in Newfoundland Province is also being planned. Originally slated to be a 2,264-megawatt project to be jointly developed with Quebec, plans for the project have been progressively scaled back over the past several years [***17***]. The original project had been criticized because of the impact that diverting the Romaine River would have on the environment and aboriginal families living in the area. Moreover, Quebec and Newfoundland officials have noted that the changing U.S. energy market made it difficult to negotiate export prices for the power. At the end of 2000, the government of Newfoundland announced that the size of the project (now to be called the Lower Churchill Power Project) had been reduced to a 1,700-megawatt powerhouse and would not require water from Quebec to complete. Construction on Lower Churchill will not begin before 2004 and should take 4 years to complete.

Mexico

Renewable energy sources remain only a small part of the energy mix in Mexico. Hydroelectricity and other renewables accounted for only 7 percent of Mexico's total energy consumption in 1999 [***18***]. The *IEO2001* reference case projects that consumption of energy from renewable sources in Mexico will increase by 2.2 percent per year, from 0.4 quadrillion Btu in 1999 to 0.7 quadrillion Btu in 2020. Renewables are expected to lose share of total energy consumption in Mexico, falling from 7 percent in 1999 to 6 percent by 2020, as a result of strong growth in oil use (3.7 percent per year).

There are few official programs aimed at increasing the amount of renewable energy used in Mexico. Concerns about pollution and greenhouse gas emissions have largely been addressed, so far, by introducing natural-gas-fired electricity generation. Nevertheless, wind power developers have estimated that Mexico's wind resources are plentiful enough that some 3,000 to 5,000 megawatts of wind capacity could be achieved, particularly in the Tehuantepec Isthmus, in the southern part of the country [***19***]. By the end of 1998, however, only 3.0 megawatts of wind capacity had been installed, and no wind capacity was added in 1999. Development of a 54-megawatt wind farm proposed in 1996 by Mexico's Federal Electricity Commission was postponed in 1999, and five other projects proposed by private companies are under negotiation. Prospects for construction appear dim; construction was postponed for all five in 1999, despite the fact that building permits have already been issued for four of them.

Western Europe

With most of the hydroelectric sites in this region already established, wind power continues to enjoy the greatest rates of growth in Western Europe. Germany, Denmark, and Spain have the fastest-growing markets for wind power in the region, and Greece, France, Belgium, and Italy, among others, have also had some success in installing wind power. Total consumption of hydroelectricity and other renewable resources in Western Europe is projected to grow by 1.8 percent per year in the *IEO2001* forecast, from 5.6 quadrillion Btu in 1999 to 8.2 quadrillion Btu in 2020 (Figure 72).

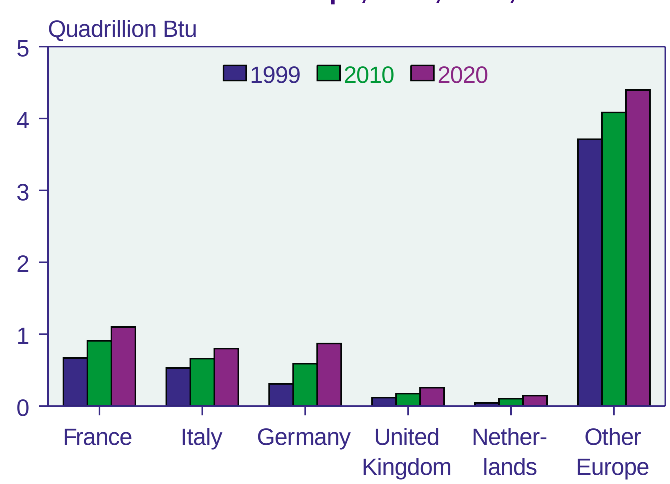
Many European governments have been attempting to increase the role of renewable energy sources through subsidies and other incentive programs in efforts to reduce emissions of carbon dioxide and other pollutants. Most of the countries in the EU assess energy taxes to keep consumer energy use in check. In Denmark, electric utilities are assigned carbon dioxide quotas, and they pay a fine of 40 Danish Krone (about $5 U.S.) for every metric ton of carbon dioxide emitted over their quota.

Germany's wind power program has been particularly successful. The country has been among the world's leaders in installing new wind capacity over the past several years. In the first 9 months of 2000 alone, 987 megawatts of wind capacity were installed in Germany, bringing the country's total wind capacity to 5,432 megawatts, more than twice the installed wind generation capacity of the United States [***20***].

In 1991, Germany enacted its Electricity Feed Law (EFL), which fixes "buy-back" prices for approved renewables at 90 percent of the average private consumer tariff. In February 2000, the government announced passage of a new law to replace the EFL, the Gesetz für den Vorrang Erneuerbarer Energien. The new law will fix tariffs for approved renewable energy projects for a 20-year period dating from the plant commissioning and will apply incremental annual price cuts [***21***]. Initial prices were set at 47.7 cents per kilowatthour for solar, 8.6 cents per kilowatthour for wind, from 9.6 to 8.2 cents per kilowatthour for biomass (depending on the amount of electricity generated), 8.4 to 6.7 cents per kilowatthour for geothermal, and 7.2 to 6.3 cents per kilowatthour for hydropower, waste, and sewage gas.

The German price scheme requires that solar energy prices be reduced by 5 percent per year from the current level of 47.7 cents per kilowatthour. Biomass prices will fall by 1 percent per year beginning in 2002. As for wind, after the first 5 years of operation, German wind tariffs will drop to 5.8 cents per kilowatthour for turbines that have generated 150 percent more power than a defined "standard turbine" limit [***22***].[17] For those turbines that do not attain the 150 percent limit, the maximum payment is to be extended by 2 months for every 0.75 percentage points for which production is below the limit.

Figure 72. Renewable Energy Consumption in Western Europe, 1999, 2010, and 2020



Sources: **1999:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **2010 and 2020:** EIA, World Energy Projection System (2001).

[17]The defined "standard turbine" or "reference turbine" is actually a series of turbine types operating at an average wind speed of 5.5 meters per second at 30 meters height with logarithmic height profile and a roughness length of 0.1 meters in specific conditions averaged over a period of 5 years using an internationally recognized and EU-approved power curve model.

For offshore wind plants that are more than 3 miles from land and come on line by 2006, a 9-year tariff of 8.6 cents per kilowatthour will be applied.

Spain has made remarkable gains in wind energy over the past several years. Installed wind capacity has grown from 73 megawatts in 1994 to 1,539 megawatts in 1999 [***23***]. In 1999, Spain was third after Germany and the United States in new installed capacity, adding 705 megawatts (Germany added 1,568 megawatts, the United States 841 megawatts). Moreover, there are already plans to install another 10,800 megawatts of wind capacity between 2000 and 2012.

To encourage the penetration of renewable energy sources, the Spanish government enacted Royal Law 2818 in December 1998, establishing a pricing regime for renewable energy plants that are connected to the national grid [***24***]. The regime allows producers to choose either a fixed price per kilowatthour generated or a variable price calculated from the average price of the market pool, plus a bonus for every kilowatthour produced. The Spanish Ministry of Energy and Industry is to update the prices every year according to the annual variation in electricity market prices. Renewable energy sources allowed under this program are small hydroelectric, wind, geothermal, wave, and primary and secondary biomass.[18] In 2000, fixed prices ranged from 5.1 to 5.5 cents per kilowatthour, and bonuses ranged from 2.2 to 2.6 cents per kilowatthour according to energy type (Table 19).

Greece made substantial additions to its wind capacity in 1999. The country more than doubled total installed capacity, adding 67.5 megawatts at nine wind projects and bringing the total installed wind capacity operating in Greece to 107 megawatts at the end of 1999 [***25***]. Greece's Ministry for Development has set a target of 350 megawatts of installed wind capacity by 2005. To achieve that aim, two government programs have been established to encourage wind installation. The Law for the Economic Development (Law 2601/98) affords wind projects a 40-percent subsidy for the cost of installation. The Operational Program for Energy-Renewables within the Community Support Framework also offered subsidies for renewable energy projects installed between 1994 and 1999.

Wind projects made some inroads in several other Western European countries in the past year. In Belgium, state utility Electrabel announced that it had signed a contract for the construction of a 100-megawatt offshore wind plant. Construction on the project, which will be the largest of its kind in Europe, is expected to begin as soon as an environmental assessment is completed. It is scheduled for completion by 2004 [***26***]. A second phase of the project aims to increase the total installed capacity to 400 megawatts.

Installation of one of the world's largest wind farms was completed in Italy in June 2000. The 170-megawatt project is located in the southern part of the country, in Campania and Puglia, near Naples. Japan's Tomen Corporation installed the wind farm at a cost of about $260 million. Electricity generated at the project will be sold to Italy's state-owned utility, Enel SpA [***27***].

There are some efforts to improve the development of wind power in France. In 1996, France's Electricite de France announced plans to implement a program to increase the amount of wind-generated electricity in the country [***28***]. The purpose of the EOLE 2005 wind program is to install between 250 and 500 megawatts of wind capacity by 2005. In October 1999, Electricite de France stated that 21 wind projects had been selected for development under the program, totaling some 200 megawatts of capacity, and another 5 projects (representing 70 megawatts of wind capacity) were under consideration [***29***].

In 2000, the United Kingdom ended the country's Non-Fossil Fuel Obligation (NFFO) tax that had been used in the past to subsidize nuclear generation (mostly) and renewable energy projects. The NFFO is to be replaced by the Renewable Energy Obligation (REO) [***30***]. The UK government announced that it had set a target to provide 10 percent of the country's electricity supply with renewable energy sources by 2010. The UK Department of Trade and Industry expects that nearly

Table 19. Price Values Under Two Incentive Programs for Renewable Energy Sources in Spain
(1999 Cents per Kilowatthour)

Renewable Energy Source	Bonus Added to the Base Price	Fixed Price
Small Hydropower	2.47	5.37
Wind Plants	2.47	5.37
Geothermal	2.56	5.46
Wave	2.56	5.46
Primary Biomass[a]	2.37	5.28
Secondary Biomass[a]	2.20	5.10

[a]Primary biomass is defined as agricultural crops grown specifically for use in biomass energy production. Secondary biomass is defined as agricultural and forest residues.

Source: International Energy Agency and the National Renewable Energy Laboratory, *IEA Wind Annual Report 1999* (Golden, CO, May 2000), p. 131.

[18]Primary biomass is defined as agricultural crops grown specifically for use in biomass energy production. Secondary biomass is defined as agricultural and forest residues.

one-half of the anticipated target will be met with wind power. The REO is scheduled to begin in October 2001 and will not expire until 2025 [***31***]. The program requires all licensed electricity suppliers to provide a specific proportion of their electricity supplies using renewable energy. Any additional costs incurred by the supplier that are associated with procuring the renewable energy source may be passed on to the consumer, but a "buyout" price has been established should the cost of generating electricity from renewable energy sources prove prohibitive.

The wind industry has had a difficult time in the United Kingdom. While the NFFO (and its related obligations in Scotland and Ireland) have contracted wind energy projects totaling some 2,676 megawatts between 1990 and 1999, only 344 megawatts of capacity were actually built and are operating [***32***]. Only 19 megawatts of new wind capacity were commissioned in 1999. The disappointing rate of completion is a result of problems with obtaining planning consent. Almost all the wind power projects submitted for planning approval in 1998 failed to secure it. Several projects did receive approval in 2000, including 4 megawatts in Hare Hill, County Durham, and 2 megawatts off the coast of Northumberland in the North Sea—the United Kingdom's first offshore wind farm [***33***]. Further, construction was completed on the 6.5-megawatt Lambrigg Wind Farm in Cumbria, England, the largest wind farm constructed in England since 1993 [***34***]. Construction also began in June 2000 on the first large wind turbine ever to be built in Ireland. The turbine is to be located in Dungannon District; no schedule for completion has been released [***35***].

Industrialized Asia

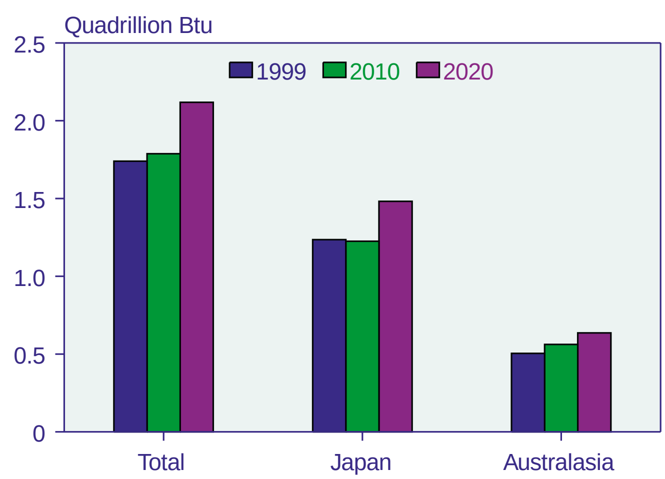
The countries of industrialized Asia (Australia, Japan, and New Zealand) have markedly different electricity energy mixes. Japan is the only one of the three countries with a nuclear generation program, supplying one-third of its electricity from nuclear power plants. Hydroelectricity and other renewable energy sources supply only 12 percent of the country'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.

The *IEO2001* reference case projects that hydroelectricity and other renewable sources in Japan will grow by 1.5 percent per year between 1999 and 2020 (Figure 73). In 2000, the Japanese Ministry of International Trade and Industry (MITI) announced plans to encourage the development of renewable resources, proposing a "Green Credit System" under which the government would issue certificates to domestic electricity producers corresponding to the amount of natural energy or recyclable energy they generate [***36***]. Electricity retail companies either would be required to buy directly a specified amount of qualifying renewable-generated electricity or would have to purchase certificates. The certificates would also be tradable between electricity companies under the new system. Ultimately, the cost of purchasing the certificates would be passed on to consumers. Plans are to introduce the scheme by mid-2001.

In 1999, Japan added 43.4 megawatts of wind capacity, increasing its total installed wind capacity by almost 40 percent to 75.1 megawatts [***37***]. Japan has set a national wind energy target to install 300 megawatts of wind capacity by 2010. Many of the existing wind turbines are located around the coast of Hokkaido, Japan's most northerly island, including the country's largest wind farm at Tomamae, with 20 megawatts of installed capacity [***38***]. The development of the Hokkaido wind potential was encouraged by the 1998 decision of Hokkaido Electric Power to pay preferential prices for wind-generated electricity of 2 yen per kilowatthour over the regular price paid for thermal-generated electricity [***39***].

Japan's Marubeni Corporation announced plans to construct a 26-megawatt wind generation facility in Kagoshima Prefecture, with 13 megawatts each installed in Nejime and Sata, the southernmost towns of the southern Japanese island, Kyushu. The project is estimated to be completed in 2002 and will become Japan's largest wind power project [***40***]. Marubeni plans to ask the New Energy and Industrial Technology Development Organization (which is an affiliate of MITI) to subsidize the project.

Figure 73. Renewable Energy Consumption in Industrialized Asia, 1999, 2010, and 2020



Note: Australasia includes Australia, New Zealand, and the U.S. Territories.

Sources: **1999:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **2010 and 2020:** EIA, World Energy Projection System (2001).

Australia has also been slow to develop nonhydroelectric renewable energy sources. At the end of 1999, the country had installed only 10 megawatts of wind capacity [***41***]. In 1999, however, the government established a Ministerial Council on Greenhouse Gas Abatement which, in turn, set a mandatory target for electricity retailers and large purchasers to acquire 2 percent of their electricity from renewable energy sources by 2010. The Council expects the legislation to be enacted in 2001 and, because of the rich wind resources available in Australia, to spur growth in the Australian wind industry. There are indications that the wind industry is already responding to the potential legislation, with more than 500 megawatts of wind power either being planned or under construction in Australia at the end of 2000 [***42***].

Several wind projects commenced in Australia in 1999, and wind farms are being developed in Queensland, New South Wales, Tasmania, and Western Australia. The 10-megawatt wind project at Blayney in the central part of the state—the largest in New South Wales—went into operation in October 2000 [***43***]. In Western Australia, the government announced plans to construct a 22-megawatt, $45 million wind farm in Albany, near the southwest coast [***44***]. It is scheduled to be completed in July 2001 and will be the largest wind plant in operation in Australia. The government estimates that the project will be able to provide 75 percent of the electric power needed in Albany. Construction of an 18.2-megawatt wind farm at Codrington in southwest Victoria is to be completed before the end of 2001. Pacific Hydro has already reached an agreement to sell the power from the project to electricity retailer Powercor and has made plans to develop a similar project in the same region within the next 5 years [***45***]. Hydro Tasmania plans to construct the 130-megawatt Woolnorth wind farm in Tasmania [***46***].

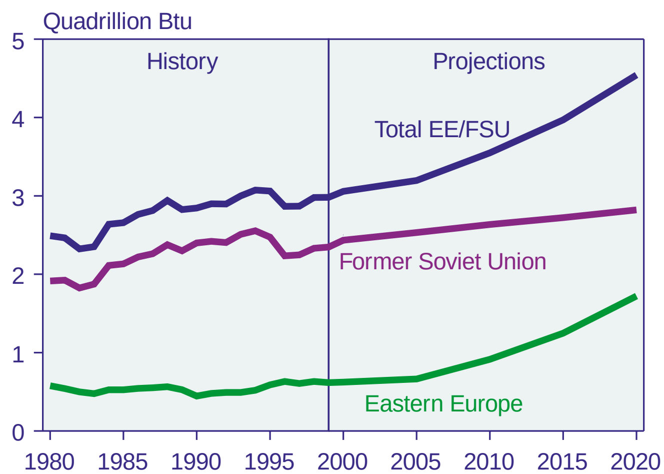
In New Zealand there are few plans to expand the use of renewable resources. The country already relies on hydroelectric power for more than 60 percent of its electricity generation and is concerned about diversifying its electricity fuel mix, because a year of low rainfall could lead to electricity shortages. As a result, most additional generating capacity is expected to be fired by natural gas rather than renewable energy sources. There are only modest proposals to increase the hydroelectric capacity of the country. New Zealand's TrustPower Company has proposed a 62-megawatt hydroelectric project at Dobson, near Greymouth [***47***]. If constructed, it would be the first of its type ever built by the private sector and the first major hydroelectric project started since the Clyde Dam in 1984.

Eastern Europe and the Former Soviet Union

Development of new hydroelectricity and other forms of renewable energy resources is expected to remain fairly low throughout the projection period in Eastern Europe and the former Soviet Union (EE/FSU). Most of the growth is expected to be in expansion and renovation of existing hydroelectric facilities that need repair after difficult economic years. In the countries of the FSU, the economy has only in the past 2 years shown signs of sustained recovery from the collapse of the Soviet Union in the early 1990s. Although the FSU economies are expected to recover over the projection period, it is expected that natural gas, a cheap and plentiful resource in Russia and several other FSU republics, will mainly be used to meet additional energy demand in the future, rather than renewables. Renewable energy use in the EE/FSU region is projected to grow by 2.1 percent per year between 1999 and 2020 in the *IEO2001* reference case, from 3.0 to 4.5 quadrillion Btu (Figure 74).

In Eastern Europe, the economies have recovered much more quickly than those of the FSU; as a result, the prospects for development of hydroelectricity and other renewables are much more optimistic in the *IEO2001* reference case forecast. Renewable energy consumption in Eastern Europe is expected to grow by 5.0 percent per year over the next two decades. As in the FSU republics, much of the growth in energy demand is projected to be met by additional natural gas use, but there are also

Figure 74. Renewable Energy Consumption in Eastern Europe and the Former Soviet Union, 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, January 2001). **Projections:** EIA, World Energy Projection System (2001).

opportunities for expanding hydroelectricity in several Eastern European countries, including Bosnia, Slovenia, and Macedonia, where undeveloped potential sites still exist.

In Russia, the FSU's largest economy and electricity consumer, hydroelectricity accounts for about 43,000 megawatts of the country's total installed capacity or about 20 percent of the total [***48***]. Almost three-fourths of Russia's hydroelectric capacity is represented by 11 power stations with more than 1,000 megawatts of capacity, including the 6,400-megawatt Sayano Shushenskoye facility in Khakassia, the 6,000-megawatt Krasnoyarsk facility in Krasnoyarsk province, and the 4,500-megawatt Batsk project in Irkutsk province—three of the four largest power generating facilities in Russia.

Only a few small nonhydroelectric renewable projects have been developed or are planned in Russia. A single 11-megawatt geothermal plant operates in Pauzhetskaya in the Kamchatka region, and there are plans to expand it by 7 megawatts before 2010. Kamchatka has rich geothermal resources, and an estimated 380 to 550 megawatts of potential geothermal capacity could be exploited. A second 80-megawatt geothermal plant is currently under construction in Kamchatka (at Mutnovsk), and the European Bank of Reconstruction and Development (EBRD) has agreed to provide $100 million for the first stage of construction on the project. Total costs are estimated to reach $500 million for the power plant and $120 million for the pipeline.

Hydroelectricity makes up more than 80 percent of Georgia's electricity generation. The country has not yet fully exploited its hydroelectric resources and has an estimated 100 billion kilowatts of potential hydroelectric capacity [***49***]. An Austrian-Georgian coalition of Strabag, Verbundplan GmbH, ABB Kraftwerke AG, and Lameyer International GmbH plans to invest up to $500 million over the next several years for hydroelectric projects. The 250-megawatt Namakhvani and the 100-megawatt Zhoneti projects are planned for construction on the Rioni River, and the 40-megawatt Minadze station is to be constructed on the Kura River. The EBRD also has approved a $39 million loan to refurbish the Inguri Hydroelectric dam, the largest in the country.

In Azerbaijan, several hydroelectric rehabilitation projects are in progress. When completed, these projects should result in an additional 671 megawatts of electricity capacity. The 360-megawatt Mingechaur hydroelectric project on the Kura River is estimated to cost $41 million and is scheduled for completion in 2001. The EBRD loaned the country $21 million to finance the replacement of generators at the plant, as well as to install environmental controls. The Islamic Development Bank and the European Union's Tacis City Twinning program are cosponsoring the effort [***50***]. Plans are also being discussed by state power company Axerenerji for a $42.5 million development of small hydroelectric stations in the autonomous Nakhichevan region [***51***]. The most promising scheme involves construction of a 23.1 megawatt capacity four-station cascade on the Gilan river.

Other proposed projects include a $9.8 million, 4.5-megawatt hydropower station on the Vaykhyr river and an $85 million, 31.5-megawatt plant on the Ordubad River [***52***]. The Islamic Development Bank has expressed interest in assisting with the projects. Azerbaijan had considered potential wind power development for Nakhichevan, but initial studies showed that every wind-generated kilowatthour would cost twice as much as a hydro-generated kilowatthour.

In July 2000, Austria's Small Hydropower Tyrol and Bosnia's Inotrade Sarajevo reached an agreement with the government of Bosnia for a 20-year design, build, operate, and transfer (DBOT) agreement with the Srednjobosanski canton authorities (in central Bosnia) and a purchase power agreement with electric power utility Elektroprivreda Bosne i Hercegovine [***53***]. The consortium plans to invest $6.03 million to construct four hydroelectric projects in central Bosnia. This marks the first investment by a foreign company in Bosnia's power sector. Three of the plants (Prokoska, Jezernica 1, and Mujakovici) are to be located on the Jezernica River. The fourth, the Botun project, is to be installed on the Kozica River. The four run-of-river plants, with a combined capacity of 3.8 megawatts, are expected to begin operating within 2 years.

Bosnia is also still negotiating with the World Bank for a $30 million loan for a project to rehabilitate several thermal and hydroelectric power plants, the so-called "Power 3 Project" [***54***]. Although negotiations have been going on since November 1999, the World Bank believes an agreement will be reached and work on the project could begin in 2001. Eventually, the total value of Power 3 could reach $225 million. In addition to the repairs planned for the electric power plants, there are also plans to improve the region's transmission grid in an effort to improve the transmission of power between southeastern Europe and other European countries by way of Bosnia.

Bulgaria has several plans for upgrading its hydroelectric facilities. Plans to rehabilitate the Gorna Arda facility in southeastern Bulgaria ran into problems in 2000 when Turkey's Ceylan Holding was forced to withdraw from the project because of financial difficulties. In November 2000, Bulgaria issued new tenders for upgrading the Gorna Arda complex and has announced that state electricity utility Natsionalna Elektricheska Kompania (NEK) will now assume Ceylan's 50-percent stake in the project [**55**]. Construction on the three-dam, 170-megawatt cascade project in the Rhodope mountains in Bulgaria's southeast were delayed repeatedly after Ceylan agreed to a joint venture with NEK in November 1998.

NEK is now seeking a partner to help finance the $220 million Gorna Arda project. Italy's Enel expressed interest in joining the project, but only if it can include the three-dam, 270-megawatt Dolna Arda cascade (located downstream from the Gorna Arda cascade) in the joint venture [**56**]. Enel argues that Gorna Arda cannot produce enough electricity to justify the $220 million investment and would have to sell electricity at 15 cents per kilowatthour to be profitable. In combination with Dolna Arda, however, the cost would fall to 8 cents per kilowatthour. Once construction begins, it is estimated that Gorna Arda would be completed within 6 years.

Plans to privatize several of Bulgaria's hydroelectric projects have not run smoothly. In 2000, the country's Privatization Agency (PA) had to ask bidders to resubmit their bids after senior politicians accused bidding companies of corrupting the sale process [**57**]. The accusations were leveled against companies that had submitted bids for the Pirinska Bistrica and Sandanska Bistrica cascades, which are considered two of the most attractive hydroelectric facilities of the 22 hydroelectric power assets, all with less than 25 megawatts of capacity, being sold by the PA. By July 2000, the PA had sold six of the offerings, including the three-dam Sandanska Bistritsa cascade to the Czech Republic's Energo-Pro and the two-dam Pirinska Bistritsa cascade to Bulgaria's Pirin 2001 [**58**].

In Romania there are a number of hydroelectric projects that have not been completed but could substantially increase the country's installed electric capacity. The country has disclosed that there are at least 12 partially built hydroelectric projects in Romania that will require foreign investment to finance their completion. In 2000, the U.S. engineering company Harza and Romania's hydropower producer Hidroelectrica signed an agreement to complete and jointly operate one of the plants, the 54-megawatt (reduced from 155 megawatts after an optimization study conducted by Harza) Surduc-Nehoiasu hydroelectric plant on the Buzau River [**59**]. Construction on the $60 million project should be completed by 2004.

Macedonia's electric utility, Elektrostopanstvo Na Makedonija (ESM), is planning a project to rehabilitate six of its largest hydroelectric plants: Vrutok, Vrben, Raven, Spilje, Tikeves, and Globocica [**60**]. Most of the plants are more than 40 years old, and their continued operation is considered vital for ESM. The six plants generated 92 percent of Macedonia's hydroelectricity supply in 1999. The total value of the project is estimated at $52 million, and it is slated for completion in 2004 (although it is already running 6 months behind schedule). In addition to reconstructing turbines, generators, and transmission facilities, replacing turbine circuits, and repairing transformers, total generating capacity is to be increased by 31 megawatts. Loans from the World Bank and the Swiss government, along with a grant worth $0.66 million from Japan and $12.1 million from ESM's own funds, will be used to complete the project.

There are also plans in Macedonia to develop the Chebren hydroelectric dam on the Crna River. Originally, the project was supposed to consist of two cascade dams, Skocivir and Galiste, along with the Chebren dam, which was to work with the Tikves hydroelectric plant to form the Crna system [**61**]. However, experts determined that the scheme would be unprofitable in that form. The government is now negotiating with an Austrian consortium led by Alpine and including Verbundplan and VA Tech Elin for a scaled-down version of the project in which only the Chebren accumulation would be constructed, thereby allowing the project to return a profit. If an agreement is reached, the project could be completed within 5 years.

There are plans to rehabilitate the 2,100-megawatt Iron Gates 1 hydroelectric plant, and Serbian utility EPS announced a tender to appoint a partner in the effort in June 2000 [**62**]. The plant is jointly owned and operated by Romania and Serbia, which plans to restore its half of the 12 turbine generators on the project. The upgrade will increase the installed capacity of each of the turbines by 15 megawatts (increasing total output by 10 percent). The project will cost an estimated $100 million and will be undertaken between 2001 and 2008. The Romanians are in the midst of restoring and upgrading their 6 generators at the plant.

Slovenia is also working to upgrade its hydroelectric facilities. Slovenian Dravska Elektrarne (DEM) is in the process of upgrading the Vuhred and Ozbalt hydroelectric plants [**63**]. This will be the second set of hydroelectric repairs and upgrades since DEM began the program in 1993. The first stage, which is nearly complete, involved raising the installed capacity of the Mariborski Otok, Dravograd, and Vuzenica hydro projects by a combined 34 megawatts. Installed capacity at Vuhred and Ozbalt will be increased by 31 and 39 megawatts, respectively.

There are only a few nonhydroelectric renewable projects underway in Eastern Europe. The World Bank is providing a $38.2 million loan for a geothermal district heating project in Poland as part of a $96.7 million plan to reduce air pollution in the country's southern Podhale Valley [**64**]. The project represents one of Eastern Europe's largest renewable energy projects, and it is one of the largest geothermal energy developments for district heating worldwide. The plant will be located in the industrial town, Nowy Targ. Total installed heat generating capacity is projected to be 135 megawatts, with 38 to 43 megawatts supplied from the geothermal source and the rest supplied from gas-fired absorption heat pumps and gas-fired peaking plants.

Wind power has also begun making some limited progress in the EE/FSU. The Japanese government has granted a 40-year loan for $10 million to increase wind power by up to 10 megawatts in western Georgia and has promised an additional $50 million for constructing additional wind projects in Kutaisi [***65***]. Latvia's government has approved the construction of 11 wind farms in the country's western Liepaja region, each with a capacity of 1.8 megawatts [***66***], over the next 2 years. However, the state utility company, Latvenergo, has argued that the wind generators are too expensive, costing the company more than $4 million in subsidy tariffs to wind generators—which is passed on to consumers. Latvia has already approved construction of 18 wind farms, but so far only one (in Venspils) has been built.

Among the Eastern European countries, Poland's Wind Power Plants Joint-Stock Company announced that it would construct a 4.5-megawatt wind power project in Postomino [***67***]. Croatia's first wind project is slated to be built off the Stupisce peninsula near Komize on Vis Island [***68***]. Construction on the 6-megawatt, $7.8 million project is scheduled to begin once the Croatian utility, HEP, has repaired transmission lines on Vis. The project is part of the Program of Development of Renewable Energy Sources (PRORES) conceived by the Zagreb-based Energy Institute Hrvoje Pozar and endorsed by the government.

Developing Asia

Developing Asia is one of the only regions in the world that has plans to continue the development of large-scale hydroelectric projects over the *IEO2001* projection period, and the projected growth rates for renewables in the region are among the highest in the forecast. In developing Asia, hydroelectric and other renewable energy resources are expected to increase by 4.0 percent per year between 1999 and 2020. For China alone, 5.1-percent annual growth in renewable energy use is projected. China, India, Vietnam, Laos, and Malaysia, among other countries in developing Asia have extensive plans to expand their hydropower resources, and all have plans to use large-scale hydroelectric projects to achieve their goals.

China

China's plans for expanding its electricity capacity through large-scale hydropower projects are progressing, but international concern remains in the forefront of some of the more controversial plans. Construction of the mammoth Three Gorges Dam project, which—at 18,200 megawatts—is the world's largest hydroelectric project under construction, continued in 2000. In addition, plans are now under consideration to install a hydroelectric project in the Himalayas that would produce two times the output of Three Gorges. The proposed project is doubly controversial in that a report in London's *Sunday Telegraph* stated that there are plans to blast a tunnel through the Himalayas and to divert waters from the Yarlung Zangbo River (the upper reaches of the Brahmaputra), which flow to India and Bangladesh [***69***].

The Three Gorges project remains controversial, with many charges of corruption and problems in the program to relocate the estimated 1.13 million people from the area that will be flooded to create the 370-mile reservoir that will serve the dam. Dam officials have said they have relocated 253,200 people thus far [***70***]. Nevertheless, work on the project has continued, for the most part, on schedule. Construction of the estimated $30 billion project is occurring in two phases. Phase I began in October 1997 and will be completed with the installation of 14 700-megawatt turbines and generators in 2006. In phase II, another 12 700-megawatt turbines will be installed. The project is expected to be wholly operational in 2009.

There is concern that electricity production from Three Gorges will far exceed demand. The 3,300-megawatt Ertan dam became operational in 1998, but in 1999 the Ertan Hydropower Development Corporation was able to sell only about 60 percent of the dam's electricity output [***71***]. The situation was exacerbated by a decision from Chongqing to take a much smaller share of power than originally agreed. Chongqing had agreed to purchase 31 percent of Ertan's output but now is accepting only 14 percent, because electricity demand growth in the municipality has not kept pace with original expectations. Ertan lost some $120 million in 1999.

As a result of the surplus electricity supply available to Chongqing and other parts of central and western China, the government has revised plans for the electricity supplies from Three Gorges Dam. Originally, the project was supposed to transmit 12,000 megawatts of the capacity to central China, 4,200 megawatts to eastern China, and 2,000 megawatts to western Chongqing. Now, however, there are plans to send 3,000 megawatts to the southern province of Guangdong and to direct another 1,000 megawatts, originally slated to go to the central provinces of Hubei and Jiangxi, to the south.

Despite the present electricity surplus, the Chinese government has plans to increase the country's hydroelectric capacity even further. In 2000, the government released its latest plans for future development, stating that it expected installed hydroelectric capacity to reach 125,000 megawatts by 2010 [***72***]. China's goal is to develop between 80,000 and 100,000 megawatts of additional hydroelectric capacity over the next two decades [***73***]. The country actually expects to export electricity over the next 20 years and has already agreed to ship 1,500 megawatts of power from the Jinghong Hydropower project to Thailand beginning in 2005, when the project is scheduled to be operational [***74***].

There are plans to expand micro-hydroelectricity in China, as well as plans to bring other renewable energy sources, such as wind and solar to the rural parts of the country. China has plans to deliver hundreds of small hydroelectric power stations to rural parts of the country where an estimated 75 million people do not have access to the national electricity grid [***75***]. The plan is to install the small hydroelectric systems to provide power in 600 rural counties by 2001, to be expanded by another 400 between 2001 and 2005 and another 400 between 2005 and 2010. China has already invested some $1.6 billion to add 1,000 megawatts of rural electric capacity each year since 1993.

The Chinese government would like to expand the amount of so-called "new" renewable energy sources and has set a target that 2 percent of the country's energy demand will be met by nonhydroelectric renewables by 2015 [***76***]. To help China meet its goal, the World Bank's Global Environmental Fund (GEF) approved a $12 million grant to install 98 megawatts of wind power in Dabancheng, Fujin, and Xiwaizi. The grant is part of a $98 million GEF project that is designed to help China diversify its energy resources and reduce its reliance on coal. At present China has only about 265 megawatts of installed wind capacity, out of a total 254,000 megawatts of installed generating capacity. Another $35.7 million GEF project co-financed with $372 million from World Bank funds would install 190 megawatts of wind power at five sites and supply about 200,000 photovoltaic (PV) and PV / wind hybrid[19] systems to households and institutions in remote areas of four northwestern Chinese provinces [***77***]. The project is scheduled for completion in 2002. The PV component is well underway, but the wind farm feasibility studies have not yet started, and that portion of the project is running behind schedule.

India

The development of renewable energy resources in India has been somewhat erratic over the past decade. The country was among the world's leaders in installing wind power in the early and mid-1990s, but by the late 1990s and into 2000 the number of new wind projects declined sharply with the end of many government incentives for the installations. Hydroelectricity, on the other hand, seems to have picked up some momentum in the last year. Hydropower accounts for about one-quarter of India's total installed electricity capacity. At present there are more than 695 dams under construction in India—for purposes of irrigation, electricity generation, and other uses [***78***].

Large-scale dam developers enjoyed a number of successes in India in 2000. In October, India's Supreme Court dismissed a petition filed by the Narmada Bachao Andolan (NBA) movement to stop completion of the 1,450-megawatt Sardar Sarovar dam project on the Narmada River [***79***]. The NBA had filed the suit, which resulted in a halt to work on the project in 1995. 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 will be required to obtain additional planning permission, including the approval of the environmental subgroup of the environment and forests ministry. Construction on the project was restarted at the end of October. When completed, 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. The project does not have any fiscal support outside the country; the World Bank and Japanese government withdrew their support in the early 1990s.

In 2000, construction resumed on India's Kol Dam in Himachal Pradesh state, another hydropower project that had been delayed for a number of years [***80***]. This 800-megawatt hydroelectric project, in contrast to the Narmada scheme, was delayed because the state was unable to secure the funds to begin construction rather than for environmental reasons. Efforts to attract private-sector investment in 1995 resulted in only one bid during an international tender, and the project was withdrawn. Instead, the Himachal government asked the National Thermal Power Corporation to build, own, and operate the Kol Dam project.

The northern Indian state of Jammu and Kashmir has signed an agreement with the National Hydropower Corporation (NHPC) that will result in an additional 2,778 megawatts of hydroelectric capacity [***81***]. The agreement involves seven projects that NHPC will construct on a build, own, operate, and transfer (BOOT) arrangement. The new projects are the 1,000-megawatt Pukhal Dul, 1,000-megawatt Busrar, 330-megawatt Kishan Ganga, 280-megawatt Uri-II, 120-megawatt

[19] Hybrid systems work with a renewable energy source that is backed up by a nonrenewable component. For example, a photovoltaic-diesel system would have a diesel generator that would start up when there was not sufficient sunlight to operate the photovoltaic component.

Sewa II, 30-megawatt Nimo Bazgo, and 18-megawatt Chaktak projects. They are estimated to cost $3.6 billion and should become operational within 7 years. Further, Jammu and Kashmir Power Development Corporation, a state-owned company, plans to pursue two additional hydro projects in the state, the 450-megawatt Baglihar and 600-megawatt Sawalkote dam schemes; however, financing for the two dams has not yet been secured.

West Bengal has also decided to try to attract private investment to develop the state's hydroelectric resources. The state relies heavily on thermal-generated electricity and, at present, has a thermal-hydro ratio of 97:3 [***82***]. In an effort to increase the diversity of the energy mix, West Bengal is now in the process of installing a 900-megawatt pumped storage project financed, in part, by the Japanese Bank for International Cooperation. The NHCP has agreed to participate in the third and fourth stages of the Teesta low dam hydroelectric project in the state, adding 100 megawatts and 132 megawatts of installed capacity to the project [***83***]. The project is scheduled to be completed by the end of 2005.

There are also a number of small hydroelectric projects planned or under construction in India. The country's Central Electricity Authority approved an 80-megawatt hydroelectric project in the northeast state of Mizoram in 2000 [***84***]. The $111 million project is scheduled for completion by 2007 and will include a 204-foot-high dam across the Bairabi River, improving navigation from the dam to Aizwal and Assam communities through a 112-mile waterway. Himachal Pradesh state signed power purchase agreements to develop 12 mini-hydro projects with a combined installed capacity of 26.3 megawatts in April 2000 and, in July 2000, signed agreements for the development of eight additional hydroelectric projects with a combined installed capacity of 254 megawatts [***85***].

Other Developing Asia

There are plans to expand the hydroelectric resources in several developing Asian countries over the next several years. Plans for expanding hydroelectric potential in Vietnam, Malaysia, Laos, and Nepal, to name a few, help to advance the *IEO2001* reference case projections for renewable energy consumption in this region. There are also a number of small, off-grid renewable projects that are being sponsored to help provide rural populations in the region with access to electricity.

In Malaysia, plans for the controversial Bakun hydroelectric project took another turn this year. The government announced in late 1997 that it planned to scale the project down from 2,500 megawatts to 500 megawatts because of the drop in electricity demand during the southeast Asian economic recession. In mid-2000, however, the government reviewed its decision and announced that it would consider restoring the project to its original size [***86***]. Critics argue that the dam would displace more than 9,000 indigenous people and would flood 70,000 hectares of rain forest [***87***]. The $13.5 billion project is being constructed by the Sarawak Hydroelectric Corporation. Three diversion tunnels already under construction should be completed before April 2001, and Bakun could be completed within 5 years [***88***]. Once the diversion tunnels are completed, work will begin on a 295-foot-high dam when the government agrees on the capacity.

In Pakistan, construction on the 1,450 megawatt, $2.2 billion Ghazi Barotha hydroelectric project is scheduled for completion in 2002. The project is being built at the confluence of the Indus and Haro Rivers in the Northwest Frontier Province. State-run Water and Power Development Authority announced it would be more than 62 percent complete in 2000 [***89***]. Although Gazi Barotha is a large-scale scheme, it is not expected to result in wide displacement of the local population. Only 115 households are to be displaced by construction, and three model villages in the vicinity of the original dwellings have already been created. The first of five 290-megawatt units is slated to become operational in August 2002, with the remaining units coming on line by the end of that year. The World Bank, Bank of Germany, European Investment Bank, and Islamic Development Bank are all helping to finance the project.

Nepal has particularly rich hydroelectric resources, with an estimated potential to develop some 83,000 megawatts of hydropower capacity. The resources remain largely untapped, however, because of the country's difficult geography and poor tax base (only an estimated 15 percent of the population of 23 million have access to electricity). In 1999, Nepal announced that it expected the country's hydroelectric capacity to double by the end of 2001, easing the acute power shortages in the country. Installed hydroelectric capacity is scheduled to increase from 289 megawatts to 570 megawatts by September 2001, as a number of power plants are commissioned. The country is heavily dependent on India for trade and hopes to develop its hydroelectricity so that it can also export excess electricity supplies and reduce its trade deficit with India [***90***]. The Bhote Koshi power station and the Kali Gandaki project are expected to begin operating in the first half of 2001, along with some other, larger projects, and the country plans to sell some 150 megawatts of excess hydroelectric power to India (up from the present 50 megawatts) during Nepal's rainy season.

There are plans to revive the Arun III run-of-river hydroelectric project in Nepal's Arun Valley. The U.S. company Eurorient Investment Group received approval from the Nepal government to construct the

402-megawatt project [***91***]. The project was originally backed by the World Bank in the mid-1990s, but the plan was eventually dropped because of the financial burdens it would have imposed on the country. Environmental groups had also criticized the project as potentially damaging to the region's forests and disruptive to the 155 households that would have been displaced by the scheme. In 1999, the Nepalese government invited the private sector to bid on the project.

Nepal's largest private hydroelectric project began generating electricity in July 2000 [***92***]. The 60-megawatt Khimti plant is located on the Khimti Khola River at Kirne, about 105 miles northeast of Kathmandu. It cost $140 million to construct and was developed by Himal Power Limited in conjunction with Norway's Statkraft.

In Laos, hydroelectric capacity is being developed as an export commodity. In mid-2000, Thailand signed a Memorandum of Understanding with Laos for a 25-year power purchase agreement to take electricity from Nam Theun 2 [***93***]. When the final agreement is signed, construction on the 920-megawatt power project in central Laos will begin. The project is expected to cost $1 billion to complete, and delivery of the Thai electricity is expected to begin in December 2006.

Vietnam is planning several hydroelectric projects to help meet growing electricity demand [***94***]. In 2000, Electricity of Vietnam submitted a feasibility study to the government for the Rao Quan hydroelectric power project, which would generate 260 million kilowatthours of power per year and whose reservoir would irrigate 12,281 hectares of rice paddy and 1,600 hectares of cereal crops. The proposed project would also help regulate the flow of the Thach Han River in Quang Tri and provide a more reliable water supply for the local population. The project would cost an estimated $140 million and would be located in the Rao Quan Valley, about 40 miles from Dong Ha and 16 miles from the Laos border.

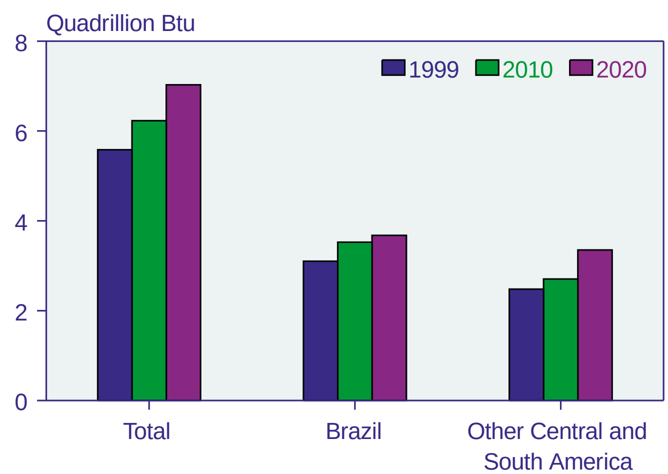
The World Bank's International Development Association approved a $150 million credit to Vietnam in 2000 to help extend electricity to about 450,000 households throughout the country, with an emphasis on households in northern Vietnam where the poorest rice farmers and cashew nut and coffee producers live [***95***]. Mini-hydro systems are to be used to supply electricity in the more remote parts of the country, but approval for that part of the project is not scheduled until 2001.

In the Philippines, the government is trying to encourage the development of hydroelectricity and geothermal electricity resources, as well as renewable generation using solar, photovoltaic, hybrids, wind, and biomass [***96***]. The government is attempting to reduce its dependence on energy imports, and the development of renewables is an important part of its scheme to provide 100 percent of the population with access to electricity. Renewable energy sources are seen as an important way in which to supply electricity to rural and remote areas that cannot be reached by the national electricity grid. The government would like to provide electricity access to some 9,000 remote villages before 2002, and there are plans to use wind, solar, or mini-hydro in about half of them [***97***]. The government plans to invest $330 million overall for the project. To date, more than 1,500 villages have been electrified.

Central and South America

Hydroelectricity remains an important source of electricity generation in Central and South America, and many countries in the region rely heavily on hydropower for their electricity supplies. In 1998, hydropower accounted for 91 percent of Brazil's total electricity generation [***98***]. Smaller Central and South American economies also depend on hydroelectricity. Paraguay generates virtually all of its electricity from hydropower, Chile about half, and oil-rich Venezuela almost three-quarters. The picture is expected to change over the projection period, however, as countries concerned about the effects of potential drought on the electricity supply attempt to diversify their electricity fuel mix, particularly by developing natural-gas-fired capacity. Hydroelectricity and other renewable resources are expected to expand by 0.6 percent per year in Brazil between 1999 and 2020 in the *IEO2001* reference case projection, and by 1.4 percent per year in the region as a whole (Figure 75).

Figure 75. Renewable Energy 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, January 2001). **2010 and 2020:** EIA, World Energy Projection System (2001).

Brazil

There are only modest plans to expand hydroelectric resources in Brazil. In 2000, plans to auction off concession licenses to build and operate 11 new hydroelectric projects were announced [**99**]. The plants will be constructed in Brazilian states Rio Grande do Sul, Minas Gerais, and Rio de Janeiro. Their combined capacity is estimated at 1,396 megawatts, and they are expected to bring electricity to 8.6 million people. At present, total installed capacity in Brazil is approximately 65,000 megawatts, in a country of about 164 million people [**100**]. The cost of constructing the plants has been estimated at close to $4.1 billion, and they are scheduled to be completed by 2004. In addition, there are plans to offer concession licenses for another 17 hydroelectric plants, with capacities between 50 and 1,200 megawatts each, sometime during 2001.

The Inter-American Development Bank approved $160.2 million in loans to support the development, construction, and maintenance of the 450-megawatt Cana Brava hydroelectric project on Brazil's Tocantins River, about 200 miles north of Brasilia in Goias State, between the towns of Calvancanti and Minacu [**101**]. The project, which is being constructed by Belgium's Tractabel, has been the object of criticism, particularly by the Brazilian environmental group, Movimento dos Atingidos por Barragens (or the Brazilian Movement of Dam-Affected People—MAB) because of concern about how Tractabel is handling the relocation of 200 families that will be displaced by Cana Brava [**102**]. MAB had requested that the Inter-American Development Bank not finance the project.

The 156-megawatt Itiquira Energetica SA hydroelectric project in Brazil's southwestern Mato Grasso state is also currently under construction. The project is being developed by U.S. NRG Energy and Sweden's government-owned utility, Vattenfall AB. Itiquira is about 30 percent complete and is expected to begin operating in 2002 [**103**].

The Brazilian government has pledged to increase the number of nonhydroelectric renewable energy projects in the country in an effort to provide electricity to people whom the national electricity grid cannot reach. In 1999, the government announced that an investment of some $25 billion would be required to bring electricity to the 20 million people without access to electricity in Brazil [**104**]. In December 1999, the Multilateral Investment Fund announced a $4.45 million grant to Brazil to help develop private-sector renewable energy pilot projects that show promise in delivering electricity to isolated parts of Brazil under the National Program for Energy Development of States and Municipalities (PRODEEM) [**105**]. The Japanese Special Fund, administered by the Inter-American Development Bank, also provided the PRODEEM program with an $898,950 grant in September 1999 for improving the management and effectiveness of the program [**106**].

Other Central and South America

Hydroelectricity and other renewable energy sources are also being expanded in other parts of Central and South America. In November 2000, Peru's 149-megawatt Chimay and the 42-megawatt Yanango hydroelectric projects that form the hydro complex known as Chinango became fully operational [**107**]. The complex cost $200 million to complete and marks the single largest private sector investment in a Peruvian energy for 30 years. The complex is owned by Enersis.

In Colombia, the government has been trying to press forward with energy privatization plans, but attacks from the communist guerrilla Colombian Armed Revolutionary Forces (FARC) movement on various energy projects have forced the government to delay its plans. Many of the attacks have been directed at pipeline projects, but in 2000 the FARC successfully attacked the 74-megawatt Bajo Anchicaya hydroelectric power plant in western Colombia and caused a blackout for nearly half of Buenaventura, Colombia's principal port [**108**]. The cost of direct losses resulting from the attack are estimated at more than $2 million; indirect losses were estimated at considerably more because port and commercial operations in Buenaventura were stopped for several days as a result of the blackout. The government was fortunate that only the 74-megawatt plant was disabled, rather than the entire 340-megawatt Anchicaya hydroelectric complex. The plant is located about 6 miles from its dam.

In Bolivia, the U.S. Initiative on Joint Implementation (USIJI) approved construction on the 83.5-megawatt Taquesi run-of-river hydroelectric project in July 2000 [**109**]. The Taquesi project will consist of two run-of-river developments and the rehabilitation of an existing 850-kilowatt project on the Taquesi and Unduavi Rivers. Construction is scheduled for completion in 2001. The project qualifies under USIJI as a carbon dioxide reduction project, and the project developer Hidroelectrica Boliviana SA will be able to offer carbon trading credits under an international greenhouse gas reduction program. Taquesi represents one of the largest projects ever approved by USIJI and is expected to reduce carbon dioxide emissions by approximately 10 million metric tons over the facility's 36-year life.

In Chile, work on Endesa's Ralco hydroelectric project on the upper part of the BioBio River was halted in February 2000 by several lawsuits [**110**]. Ralco would be the largest hydroelectric project in Chile at 570 megawatts, and if it is completed it will add 18 percent to the capacity of Chile's central electricity grid. The project is scheduled to become operational in 2003. In January 2000, former Chilean President Frei granted the concession for construction, but the comptroller-general objected, causing construction to stop. The dam has been controversial since its construction was first announced in 1994. It will flood almost 8,600 acres and force the relocation of the indigenous Pehuenche residents.

There is some urgency associated with increasing the installed electricity capacity in Chile. Electricity demand in the country is expanding by about 8 percent per year. In 1998, three new gas-fired plants added 1,000 megawatts to Chile's central grid, increasing its capacity by a fifth, but no other plants are due to come on line until 2003, when Ralco is scheduled for completion [***111***]. While there are plans to expand the gas-fired capacity in the long run, it has been reported that heavy worldwide demand for combined-cycle plants means that none are available to Chile until at least 2003.

There are also some efforts to increase the penetration of nonhydroelectric renewables in Chile. By some estimates, Chile may have geothermal generating capacity approaching 16,000 megawatts, and the government hopes that geothermal energy will become a significant part of the country's national electricity system over the next 10 to 15 years [***112***]. Unfortunately, geothermal is not, at present, competitive with hydroelectricity. Chile's state oil company, Enap, has estimated that geothermal power plants will cost $650 to $1,500 per kilowatt to install, compared with $1,000 per kilowatt for hydroelectric and $300 per kilowatt for gas-fired plants [***113***]. Geothermal pilot projects are being developed for heating greenhouses, drying fruit, and fish farming.

Wind power in Chile has only begun to be developed, despite favorable wind resources. In October 2000, a wind-diesel hybrid village power project on the island, Isla Tac, Chiloe, began operation [***114***]. The project was funded by the U.S. Agency for International Development and Chile's Comision Nacional de Energma. The 15-kilowatt project works with a 12-kilowatt backup diesel generator. The system is to be used by a rural community of 350 people.

In Argentina—as in Brazil—there is a concerted effort to supply electricity to some of the more remote, isolated population. Although 95 percent of the total Argentine population has access to electricity, an estimated 30 percent of the rural population lacks electricity and other basic infrastructure [***115***]. In 1995, the Argentine Secretaria de Energia created the Programa de Abastecimiento Eléctrico a la Población Rural de Argentina (PAEPRA) to develop off-grid electricity to residents in rural locations and to provincial public services such as schools, police stations, and health centers. The goal of PAEPRA is to ensure that 1.4 million people (about 314,000 households) and 6,000 public services are provided with electricity.

A component of the PAEPRA, the Proyecto de Energia Renovable en el Mercado Eléctrico Rural (PERMER), is being implemented jointly by the Argentine government and the World Bank in eight provinces. PERMER will provide electricity for lighting, radio, and television to about 70,000 rural households and 1,100 provincial public service institutions through private developers, using mainly renewable energy systems. The project is to be completed before 2006. The estimated total cost of PERMER is $120.5 million, which will be financed by the World Bank ($30 million loan), Global Environment Facility ($10 million grant), the Electricity Investment Development Fund ($26.5 million subsidy to customers), the energy developers ($44 million), and the consumers ($10 million).

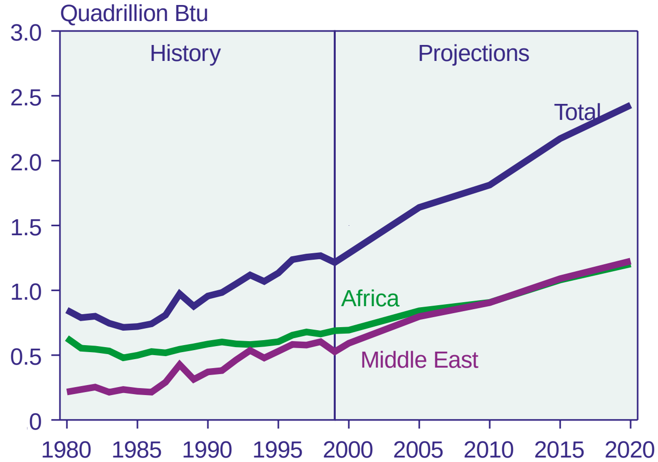
Africa and the Middle East

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 developed their hydroelectric resources to any extent. Hydroelectricity accounts for 45 percent of Turkey's total installed capacity (10,000 megawatts out of 23,000 megawatts) and for 7 percent of Iran's total (2,000 megawatts out of 30,000 megawatts) [***116***]. In Africa, Egypt and Congo (Kinshasa) have the largest volumes of hydroelectric capacity, but other countries, including Ivory Coast, Kenya, and Zimbabwe, are almost entirely dependent on hydropower for their electricity. (Many countries in Africa are generally lacking in the 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 2.4 quadrillion Btu in 2020 (Figure 76).

Nonhydroelectric renewable energy sources have not been developed to a large extent in the Africa/Middle East region and account for almost none of the region's installed electricity capacity. There are some efforts to bring small, off-grid projects to isolated parts of Africa and the Middle East to provide access to electricity to dispersed rural populations.

The most important wind energy project developments in Africa have taken place in Egypt and Morocco [***117***]. Morocco has set a target of electrifying the rural parts of the country by 2010 (currently only 15 percent of the rural population has access to electricity) [***118***]. The country intends to invest some $3.7 billion in energy projects through 2003, a portion of which will go toward rural electrification projects, including wind projects. In late 2000, a $56 million, 50-megawatt wind farm went into operation at Koudia el Beida near the Straits of

Figure 76. Renewable Energy Consumption in Africa and the Middle East, 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, January 2001). **Projections:** EIA, World Energy Projection System (2001).

Gibraltar. In August 2000, the state-owned Office National de l'Electricité issued a tender for the construction of 200 megawatts of wind capacity in two wind farms to be located in the northern and southern area of Tangiers and Tarfaya [***119***]. The total cost of construction for the two wind farms has been estimated at $200 million.

Egypt is planning to expand its use of nonhydroelectric renewables over the next several years. The country plans to build a 30-megawatt solar power plant at Kureimat funded in part by the World Bank's GEF, which will pay the difference between constructing the solar plant and a comparable-sized thermal unit. In addition, the Netherlands is funding a 60-megawatt wind project in the Suez Canal area.

South Africa and Uganda have plans to build substantial hydroelectric projects during the forecast period. U.S. independent power producer AES is expected to construct the $520 million, 250-megawatt Bujagali dam on the Nile in Uganda [***120***]. The project is scheduled to become operational in 2005 and will increase Uganda's existing power supply by 40 percent [***121***]. Construction of South Africa's Lesotho Highlands Water Project, which includes six dams on the Senqu River, represents Africa's largest infrastructure project. The project is the subject of international criticism because of the displacement of more than 30,000 people. In 1999, Lesotho came under further criticism from the World Bank—which has provided funds for the hydro project—for corruption when European, Canadian, and South African contractors involved with the $8 billion project were charged with paying bribes to the former chief executive of the Lesotho Highlands Development Authority [***122***].

In the Middle East, Turkey has the most ambitious expansion plans for hydroelectricity. Turkey continued, despite strong international criticism, to pursue its plans to construct the 1,200-megawatt Ilisu hydroelectric project [***123***]. Ilisu is part of the Southeastern Anatolian Water Project, known as GAP. When completed, GAP would consist of 22 dams and 19 hydroelectric plants on the Euphrates and Tigris Rivers. The project was conceived in the late 1970s and, if taken to full completion, will cost in excess of $32 billion. Ilisu alone will cost an estimated $2 billion to construct and will be the fifth largest dam in the world. Critics cite the destruction of countless architectural treasures as the reservoir that is required to support the dam project will flood the ancient Roman town of Zeugma, among others, and will cause the displacement of between 25,000 and 75,000 people [***124***].

There is mounting pressure on companies and export credit agencies to withdraw support from the Ilisu project. The Swedish company, Skanska, which had held a 24-percent stake in the project, withdrew in November citing concerns about the project's failure to meet international standards [***125***]. If the project remains on schedule, the dam will be completed by 2008 [***126***].

There are efforts to introduce wind power in Turkey as well, and the country plans to begin construction on its first large-scale wind project at the end of 2000. The installation of 120 megawatts of wind capacity is supposed to be the first phase of a 350-megawatt wind power development scheme. The Turkish government has scheduled the release of another renewable energy tender offer in April 2001 [***127***]. The first part of the project will be a 30-megawatt wind farm on the cliffs of the Dardanelles straits, west of Istanbul. Two other projects to be located in the Cesme area near the city of Ismir will have a combined installed capacity of 90 megawatts. Construction of the three projects is to be completed by the end of 2001.

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Electricity

Electricity consumption nearly doubles in the IEO2001 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 2001* (*IEO2001*) reference case, worldwide electricity consumption is projected to increase at an average annual rate of 2.7 percent from 1999 to 2020 (Table 20). The most rapid growth in electricity use is projected for developing Asia, at 4.5 percent per year, and by 2020 developing Asia is expected to consume more than twice as much electricity as it did in 1999. China's electricity consumption is projected to triple, growing by an average of 5.5 percent per year from 1999 to 2020. The expected growth rate for electricity use in Central and South America is 4.0 percent per year, and in the developing world as a whole the projected average growth rate is 4.2 percent per year.

The projections for electricity consumption in the developing world depend primarily on assumptions with regard to growth in population and per capita income. In countries where population is expected to remain stable, such as China, per capita income growth is the more important component of electricity demand growth. In countries where substantial population growth is anticipated, such as the nations of South America, per capita income growth is less important as a determinant of growth in electricity demand.

Electricity consumption in the industrialized world is expected to grow at a more modest pace of 1.8 percent per year, considerably lower than has been seen in the past. (The three industrialized economies of North America—Canada, Mexico, and the United States—accounted for roughly one-third of the world's electricity market in 1999.) 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.

The *IEO2001* reference case forecast is framed by low and high economic growth case projections. In the *IEO2001* high economic growth case, annual growth in global electricity consumption is projected to average 3.3 percent from 1999 to 2020. In the low economic growth case, electricity consumption is projected to grow by an average of 1.7 percent per year (Figure 77).

In 1999, coal provided 34 percent of the energy used for electricity generation throughout the world (Table 21), accounting for the largest market share among the

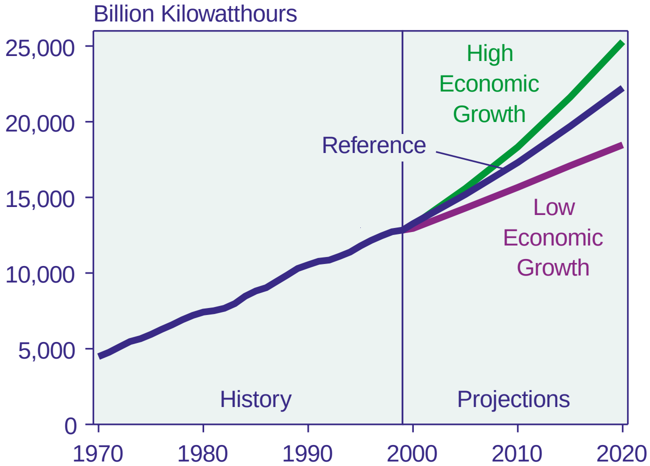
Table 20. World Net Electricity Consumption by Region, 1990-2020
(Billion Kilowatthours)

Region	History		Projections				
	1990	1999	2005	2010	2015	2020	Average Annual Percent Change, 1999-2020
Industrialized Countries	**6,385**	**7,517**	**8,580**	**9,352**	**10,112**	**10,888**	**1.8**
United States	2,817	3,236	3,761	4,147	4,484	4,804	1.9
EE/FSU	**1,906**	**1,452**	**1,622**	**1,760**	**1,972**	**2,138**	**1.9**
Developing Countries	**2,258**	**3,863**	**4,988**	**6,191**	**7,615**	**9,203**	**4.2**
Developing Asia	1,259	2,319	3,088	3,883	4,815	5,856	4.5
China	551	1,084	1,533	2,035	2,635	3,331	5.5
India	257	424	545	656	798	949	3.9
South Korea	93	233	294	333	386	437	3.0
Other Developing Asia	357	578	716	858	996	1,139	3.3
Central and South America	449	684	844	1,035	1,268	1,552	4.0
Total World	**10,549**	**12,833**	**15,190**	**17,303**	**19,699**	**22,230**	**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, January 2001). **Projections:** EIA, World Energy Projection System (2001).

Figure 77. 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, January 2001). **Projections:** EIA, World Energy Projection System (2001).

energy fuels.[20] Coal is expected to remain the most widely used fuel for electricity generation through 2020, when its share of the total is projected to be about 31 percent (Figure 78). China and the United States accounted for one-half of the world's steam coal consumption in 1999, and in 2020 (assuming no changes in current environmental laws and policies) they are expected to consume nearly two-thirds of all the coal used to generate electricity.

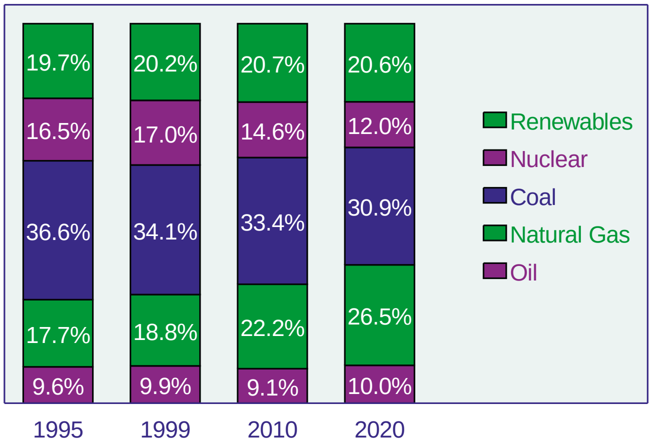
Nuclear power accounted for 17 percent of the energy used for electricity generation in 1999 and natural gas 19 percent. In the reference case forecast, nuclear is expected to lose and natural gas to gain market share. The nuclear share is projected to fall to 12 percent in 2020, and the gas share is projected to increase to 26 percent. Renewables, including hydropower, are projected to account for 21 percent of total energy use for electricity generation in 2020, up slightly from their 20-percent share in 1999.

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**	**91.6**	**97.2**	**103.5**	**108.0**
Oil	5.7	6.5	5.4	5.3	5.5	5.9
Natural Gas	9.7	11.6	15.6	18.3	23.1	27.4
Coal	27.7	29.5	32.1	33.4	34.0	34.3
Nuclear	19.4	20.6	20.9	20.9	20.5	19.1
Renewables	14.7	15.6	17.5	19.4	20.4	21.3
EE/FSU	**26.4**	**23.8**	**25.9**	**27.0**	**28.9**	**30.8**
Oil	2.8	2.4	3.1	3.5	4.2	4.7
Natural Gas	10.6	10.3	11.1	12.3	14.4	15.9
Coal	7.4	5.4	5.4	4.5	3.3	2.8
Nuclear	2.5	2.7	3.2	3.1	3.1	2.8
Renewables	3.1	3.0	3.2	3.5	4.0	4.5
Developing	**38.1**	**40.9**	**52.3**	**63.1**	**75.0**	**86.6**
Oil	5.1	5.7	6.9	8.3	10.0	12.0
Natural Gas	4.8	6.0	8.4	11.0	13.6	16.4
Coal	16.8	15.8	20.4	24.7	29.2	32.6
Nuclear	1.4	1.9	2.6	3.4	4.1	5.1
Renewables	10.1	11.5	14.1	15.8	18.2	20.5
Total World	**141.7**	**148.4**	**169.8**	**187.3**	**207.4**	**225.4**
Oil	13.6	14.6	15.4	17.0	19.7	22.5
Natural Gas	25.1	27.9	35.2	41.7	51.0	59.7
Coal	51.9	50.7	57.8	62.5	66.5	69.7
Nuclear	23.3	25.3	26.7	27.4	27.7	27.1
Renewables	27.9	30.0	34.8	38.7	42.5	46.4

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, January 2001). **Projections:** EIA, World Energy Projection System (2001).

Figure 78. Fuel Shares of Energy Use for Electricity Generation, 1995, 1999, 2010, and 2020



Sources: **1995 and 1999:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **2010 and 2020:** EIA, World Energy Projection System (2001).

Oil has played a decreasing role in electricity generation for several decades. As recently as 1978, oil accounted for nearly one-fourth of the world's energy consumption for power generation, but its use has since been largely displaced by nuclear power and natural gas. Oil's share of the global electricity fuel market was 10 percent in 1999 and is projected to remain at 10 percent in 2020.

The remainder of this chapter provides a brief overview of world electricity generation and fuel use, followed by highlights of developments in national electricity industries in the United States (where electricity deregulation is proceeding in many States) and the rest of the world.

Primary Fuel Use for Electricity Generation

Natural Gas

Natural gas is becoming the fuel of choice for new electricity generation investment around the globe. Over the 1999 through 2020 forecast period, natural gas use for electricity generation is expected to more than double (Table 21), as technologies for gas-fired generation continue to improve and ample natural gas reserves are exploited. Contributing developments include a desire to move away from reliance on nuclear power and coal in Western Europe; uncertainty about national and international policies (such as the Kyoto Protocol) that could affect coal use; an expected decline in nuclear power capacity in the United States; increasing substitution of natural gas for coal in Eastern Europe and the former Soviet Union (FSU); and fuel diversification to reduce reliance on hydroelectricity among the developing nations of South America.

The FSU and the Middle East each account for 35 percent of the world's proved natural gas reserves [***1***]. The FSU accounted for more than one-third of natural gas usage in electricity generation worldwide in 1999, and natural gas provided 51 percent of the energy used for electricity generation in the region. In 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 their reliance on natural gas for electricity generation, from 10 percent in 1999 to 26 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 14 percent in 1999 to 28 percent in 2020, and in Canada the gas share is expected to grow from 3 percent in 1999 to 10 percent in 2020. Although a sharp increase in natural gas prices in late 2000 has cast some doubt on energy strategies that would rely entirely on natural gas for new generating capacity, it is expected that the higher prices will lead to more spending on exploration and development in the longer term, reducing prices and restoring the competitiveness of gas as a generation fuel. In addition, imports from Canada are expected to provide a growing supply of natural gas to U.S. generators.

The most rapid increase in natural gas use for electricity generation in the industrialized world is projected for Western Europe. After the oil crisis of 1973, European nations 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 directive restricted the use of gas in new power plants, and the natural gas share of the electricity market in Western Europe fell from 9 percent in 1977 to 5 percent in 1981, where it remained for most of the 1980s. In the early 1990s, the growing availability of reserves from the North Sea and increased imports from Russia and North Africa lessened concerns about gas supply in the region, and the EU directive was repealed. In 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.

The relative accessibility of natural gas resources will in large measure determine Europe's reliance on gas as a fuel for electricity generation. Almost three-quarters of the world's natural gas reserves are in the former Soviet union and the Middle East. For some regions, including Western Europe, increased access to natural gas by pipeline or LNG tanker will be needed in order for the expected increases in gas-fired electricity generation to be realized.

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 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.

Coal

In 2020, coal is expected to account for 31 percent of the world's electricity fuel market, slightly lower than its 34-percent share in 1999. The United States accounted for 38 percent of all coal use for electricity generation in 1999 and developing Asia 25 percent. In the *IEO2001* forecast, the coal share of U.S. electricity generation is expected to decline slightly, to 44 percent in 2020 from 51 percent in 1999; and in developing Asia the coal share is projected to decline to 52 percent in 2020 from 54 percent in 1999.

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 9 percent in 2020.

Nuclear Power

The nuclear share of energy use for electricity production is also expected to decline in most 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 the United States, the nuclear share is projected to drop from 20 percent of the electricity fuel market in 1999 (second behind coal) to 12 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 decline to 13 percent in 2020. In Western Europe, the nuclear share of the electricity fuel market is projected to fall from 35 percent in 1999—more than any other energy source—to 24 percent in 2020. (Finland and France are alone among Western Europe's nuclear power producers in remaining committed to expanding 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 38 percent by 2020 in the *IEO2001* 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 7 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, including hydropower, accounted for 20 percent of the world's energy use for electricity generation in 1999. Its share is expected to rise only slightly, to 21 percent, in 2020. Of the world's consumption of renewable energy for electricity production in 1999, the United States and Canada together accounted for almost 30 percent of the total, Central and South America 19 percent (despite generating just 5 percent of the world's electricity), Western Europe 19 percent, and developing Asia 15 percent.

In 1999, renewables accounted for 11 percent of electricity production in the United States and 62 percent in Canada, where hydroelectric power has been extensively developed. Their shares are generally expected to be maintained through 2020. In North America and throughout the world, generation technologies using nonhydroelectric renewables are expected to improve over the forecast period, but they still are expected to be relatively expensive in the low price environment assumed in the *IEO2001* 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, and 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. Norway led Europe in hydroelectricity production in 1999, accounting for 26 percent of the region's total [***2***], followed by Sweden at 15 percent and France at 14 percent. 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 also actively developing their nonhydroelectric renewable energy resources, 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 hydropower projects are expected to become operational during the forecast period. Developing Asia relied on renewables for 20 percent of its electricity production in 1999, and that share is expected to remain stable through 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 only 10 percent. Energy security concerns, as well as environmental considerations, have led most nations to reduce their use of oil for electricity generation. In regions where oil continues to hold a significant share of the generation fuel market, however, such as the FSU and the Middle East, increases in its share are expected. As a result, the oil share of world energy use for electricity production is projected to remain at 10 percent in 2020.

Developing Asia accounted for 17 percent of the world's consumption of oil for electricity generation in 1999, when 10 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 decline slightly, to 9 percent in 2020. In the FSU region, which accounted for 14 percent of the world's consumption of oil for electricity generation in 1999, oil's share is projected to increase to 17 percent in 2020 from 11 percent in 1999. In the Middle East, oil supplied 35 percent of the energy used for electricity generation in 1999, and its share is projected to grow to 38 percent in 2020.

Regional Highlights

United States

Industry Consolidation Continues

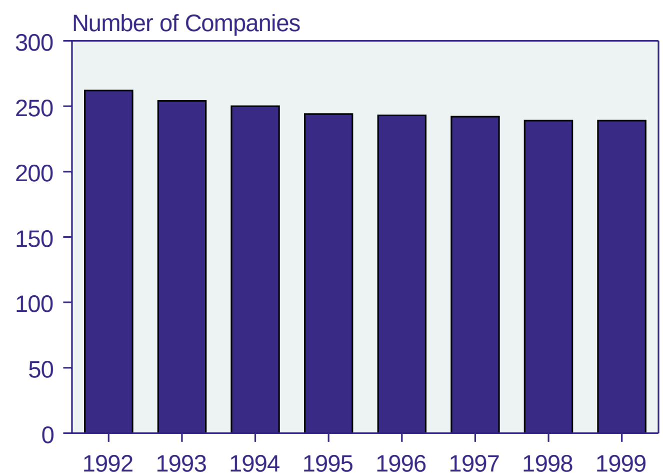
Between 1996 and 1998 there were an average of 12 merger and acquisition announcements annually in the U.S. electricity industry. There are currently 239 investor-owned public utilities, down by 23 (9 percent) since 1992 (Figure 79). Employment in the U.S. electric service industry has fallen from 440,000 jobs in 1992 to 360,000 in 1999. Employment reductions have been an anticipatory reaction to industry consolidation as well as a result of many mergers and acquisitions themselves. The latest round of industry consolidation has occurred amid a wave of deregulation at both the State and Federal levels.

It should be noted that this is not the first time the industry has gone through a period of great change. Shortly after Thomas Edison gave birth to the industry when he opened his Pearl Street generator in New York in 1882, scores of electricity companies were established. By the early 1900s, Chicago alone had 47 electricity companies [***3***]. In the 1920s a wave of industry consolidation ensued reaching a peak of over 300 mergers per year during the mid-1920s [***4***]. By 1929, seven holding companies accounted for 60 percent of U.S. generating capacity [***5***]. Growing economies of scale of larger generation units in part helped move this consolidation along.

During the 1930s, several major holding companies went bankrupt leading to a Federal Trade Commission investigation and the enactment of the Public Utility Holding Company Act. Subsequently, several hundred holding companies were spun off, and by the early 1950s there were well over 500 investor-owned utilities (IOUs). But once again the industry consolidated, and the number of IOUs fell to roughly 270 in the late 1960s.

As in the 1930s, the most recent wave of merger and acquisition activity stems in part from Federal policy reforms. The Public Utility Regulatory Policies Act of 1978 (PURPA) required transmission companies to interconnect with and buy whatever capacity any

Figure 79. Investor-Owned Utilities in the United States, 1992-1999



Source: Energy Information Administration, *Electric Sales and Revenues*, DOE/EIA-0540 (Washington, DC, various years).

facility meeting the criteria for a "qualifying facility"[21] had to offer, and to pay that facility the utility's own incremental or avoided cost of production [***6***]. Open access was pushed a step further with the passage of the Energy Policy Act of 1992 (EPACT), which allowed for wholesale power competition by creating a new class of wholesale generator and expanded the power of the Federal Energy Regulatory Commission (FERC) to order open transmission access [***7***].

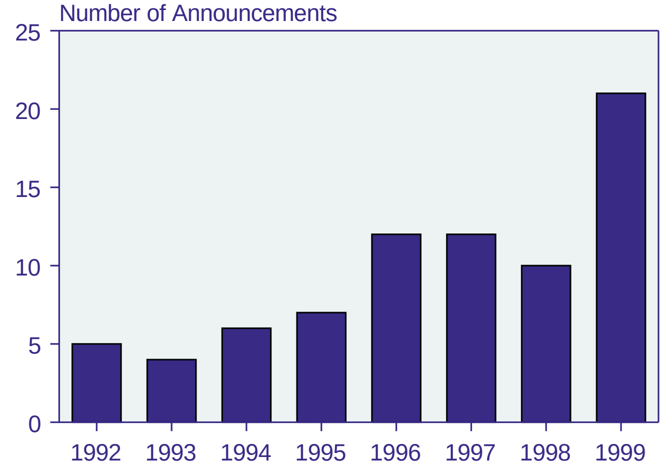
EPACT also promoted eventual competition at the retail level. Based on the mandate derived from EPACT, the FERC issued Orders 888 and 889. Order 888 required all public utilities that own, control, or operate facilities used for transmitting electricity in interstate commerce to provide open access to transmission services for other power producers [***8***]. Order 889 required the establishment of an electronic trading system similar to the one that had evolved in the natural gas market only a few years earlier.

The corporate response to these policy changes was the creation of a rapidly growing independent power industry, which made for a more competitive atmosphere in generation. In 1998, there were 109 independent power producers active in the United States [***9***], and they accounted for about 7 percent of existing capacity. More than half of all new capacity additions in the United States are expected to be supplied by independent power producers [***10***].

The FERC may have also eased the way for many mergers and acquisitions when it adopted a new merger and acquisition policy in 1996. The agency adopted the Department of Justice/Federal Trade Commission merger guidelines as a screening device to determine whether a proposed merger would cause an unacceptable increase in market power. In addition, the updated policy reflects the important role that competition is expected to play in protecting the public interest since the passage of EPACT and the implementation of open transmission access.

The new policy uses a quantitative screen, employing an Herfindahl-Hirschman index, to determine a potential merger's impact on competition.[22] The new policy also attempts to reduce the procedural steps involved in a review along with the review time for most mergers to 12-15 months. Since the new policy was implemented, more merger and acquisition approvals have been made by the FERC, and announcements of mergers and acquisitions have accelerated [***11***] (Figure 80).

Figure 80. Mergers and Acquisitions in the U.S. Electricity Industry, 1992-1999



Source: Ausma Tomserics, Edison Electric Institute, personal communication, March 13, 2001.

What distinguishes the current era of industry consolidation from earlier post-war consolidation is the size of the companies involved in the merger and acquisitions. Up until the 1990s, post-war mergers and acquisitions generally involved the purchase of relatively small IOUs. The 1990s, in contrast, have seen some of the largest companies in the industry involved on both sides of the merger and acquisition transaction. During the past decade, U.S. electricity companies have also made substantial acquisitions overseas, particularly in the United Kingdom, Australia, and South America; and foreign companies are now beginning to invest in U.S. electricity. The current wave of industry consolidation is also distinct in that the industry has also merged extensively with the natural gas industry.

In the current wave of consolidation, acquiring companies have been willing to pay a steep premium over book values, indicating perhaps that certain operational synergies may be realized through this expansion. By 2000, this premium had increased to roughly double the book value of the acquired companies (Figure 81).

Several large mergers took place or were announced in 2000. The largest involved the FPL Group of Florida and Entergy Corporation of Louisiana. The debt and equity value of the merged companies equals $27 billion, and the combined company will become the biggest utility in the United States. Both companies are major producers of nuclear power, which also continues a trend among the nuclear power industry toward greater concentration (see discussion in the Nuclear Power chapter

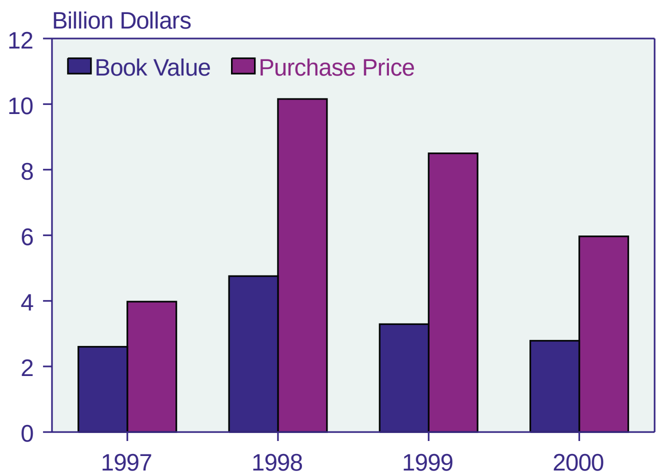
[21] A "qualifying facility" is defined as a cogeneration or small power production facility that meets certain ownership, operating, and efficiency criteria established by the FERC.

[22] The Herfiindahl-Hirschman index is a commonly accepted measure of market concentration. It is calculated by squaring the market share of each firm competing in the market and then summing the resulting numbers. The index takes into account the relative size and disribution of firms in a market and approaches zero when a market consists of a large number of firms of relatively equal size. For more infomation, see U.S. Department of Justice, web site www.usdoj.gov/atr/testimony/hhi.htm.

of this report). Together Entergy and FP&L will account for 11 percent of U.S. nuclear power generation. The value of the transaction was estimated at $13.9 billion [***12***]. In April 2000, Entergy and Koch Industries (of Kansas) agreed to merge Koch's natural gas pipeline operations with Entergy's power trading and fuel procurement operations.

In August 2000, FirstEnergy Corporation of Ohio agreed to acquire GPU, Inc., of New Jersey. When the acquisition is completed, FirstEnergy will become the sixth largest energy company in the United States [***13***]. GPU, which has divested most of its power plants over the last few years, is now largely a distribution company. The value of the transaction is estimated at $4.5 billion in cash and stock and another $7.4 billion in debt for a total of $11.9 billion. GPU serves customers in New Jersey and Pennsylvania; FirstEnergy services customers in Ohio and Pennsylvania.

Figure 81. Book Values and Purchase Prices of Acquisitions in the U.S. Electricity Industry, 1997-2000



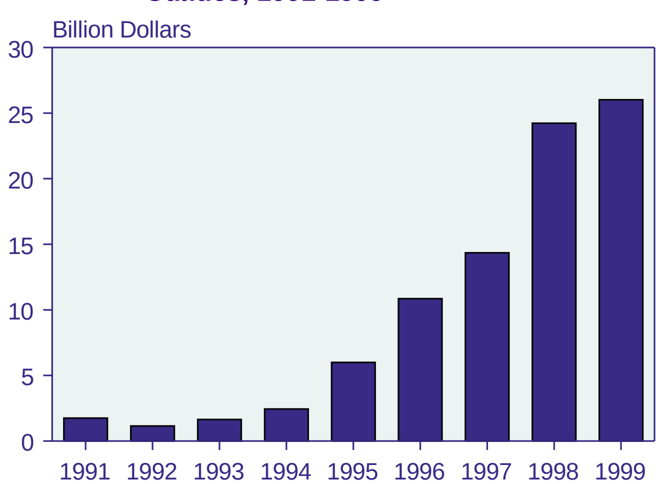
Note: Transactions are as of October 6, 2000.
Source: Edison Electric Institute, *Divestiture Action and Analysis* (various isues).

The next largest merger announcement in 2000 also involved two very large utility companies and holders of nuclear generation assets. In October 2000, Unicom (Illinois) and PECO Energy (Pennsylvania) completed their merger. The combined company name is Exelon. Exelon will have $12 billion in revenues and will be the largest nuclear power company in the United States, accounting for 17 percent of total capacity. The value of the transaction was estimated at $7.8 billion [***14***].

International Investment in U.S. Electricity Industry Grows

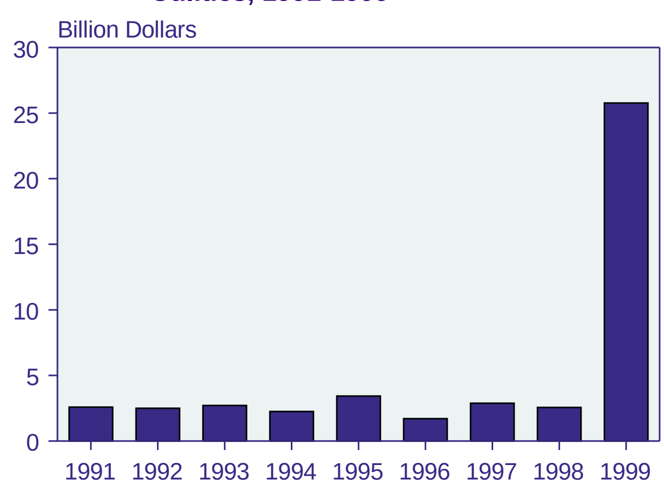
Although U.S. companies have invested heavily overseas since the early 1990s (Figure 82), foreign companies have until recently invested little in U.S. electricity. However, several companies from the United Kingdom (UK) have recently acquired U.S. electricity assets, a development heretofore rare in the U.S. electricity industry (Figure 83). The largest of these acquisitions involved Scottish Power's purchase of PacifiCorp of Oregon. The value of the acquisition was estimated at $12.9 billion. The merger was completed November 1999.

Figure 82. U.S. Direct Investment in Overseas Utilities, 1991-1999



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).

Figure 83. Foreign Direct Investment in U.S. Utilities, 1991-1999



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).

U.S. Electricity Deregulation: The California Experience

California's recent experience with electricity deregulation could have repercussions for the many governments around the world that are seeking to achieve electricity reform. Just as the earlier experience with reforms in the United Kingdom encouraged others to adopt similarly aggressive attempts at liberalizing electricity markets, the recent Californian experience with electricity reform may give some pause about reforming too quickly or ambitiously . . . or at all.[a] Motivating California's electricity reform efforts was the desire to reduce some of the highest electricity rates in the United States. In 1996, California's average electricity revenue per kilowatthour sold, at 9.54 cents, was 38 percent higher than the average U.S. rate.[b] California's residential consumers paid 36 percent more than the average U.S. residential consumer, and industrial users in the State paid 52 percent more than average.

California began its recent experience with electricity reform on January 1, 1998, when Assembly Bill 1890 (A.B. 1890) became effective. Influenced strongly by electricity reforms undertaken in the United Kingdom almost a decade earlier, California created a new means of electricity exchange and allowed consumers greater choice in selecting their electricity suppliers. California's reforms implemented a pricing mechanism that would recover "stranded" electricity costs, most of which were related to past investments in nuclear power and uneconomical power purchase contracts. To ensure that consumers benefited during the transition period, California required that the State's three major utilities provide their residential and small commercial customers a 10-percent rate reduction, freezing rates at 10 percent below the prevailing rates as of June 10, 1996, until at least April 2002. What was essentially a performance-based rate (PBR) system was adopted during the transition period.[c]

California's electricity reform addressed the industry's stranded cost problem. Stranded costs were allocated to all classes of customers in accordance with the amount of electricity they consumed. The State has attempted to pay down stranded costs through the issuance of bonds to be financed over a transitional period, but in practice the financing of the bonds added to consumers' electricity bills and offset some of the impact of the rate reduction discussed above. In essence, the rate reduction was financed by the bonds used to recover the stranded costs, and the costs of the financing were transferred to consumers. The financing is due to be completed either by March 31, 2002, or at the time that all authorized costs for utility generation assets (stranded costs) have been recovered.

A.B. 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.[d] Consumers have been reluctant, however, to switch from their incumbent suppliers. They may have been discouraged by the retail rate caps and by the fees charged for making a switch. The multinational conglomerate Enron, for instance, exited the California retail market only 2 months after beginning operation, due to a low consumer signup rate. Whatever the reason, the introduction of electricity marketing in California was less successful than it has been in the Scandinavian countries, Australia, and the United Kingdom.

A.B. 1890 attempted to reconstruct California's electricity supply industry along its three distinct components: generation, transmission, and distribution. An electricity pool, the California Power Exchange (PX), and an Independent System Operator (ISO) were created. The California PX and ISO were launched in March 1998. The ISO was given a mandate to operate the high-voltage transmission lines owned by the State's three dominant investor-owned utilities, Pacific Gas & Electric, Southern California Edison, and San Diego Gas & Electric.

The purpose of the PX is to act as a market for buying and selling electricity. All investor-owned utilities are required to compete in a power pool to sell their electricity, and independents may compete in the pool on a voluntary basis. The power pool works in the following fashion: suppliers and consumers of electricity submit bids to the PX for electricity needed both during the next day and during the next hour time periods. The PX then calculates the resulting demand and supply curves to determine a market clearing price.

(continued on page 127)

[a]For a description of the electricity reforms undertaken in the United Kingdom, see Energy Information Administration, *Electricity Reform Abroad and U.S. Investment*, DOE/EIA-0616 (Washington, DC, October 1997).

[b]Energy Information Administration, *Electric Power Annual 1997*, Vol. II, DOE/EIA-0348(97/2) (Washington, DC, October 1998), p. 22.

[c]Performance-based rates are essentially caps on prices, rather than on profits as was the case under the earlier method of regulation. Performance-based ratemaking is intended to allow electricity suppliers to profit more directly from efficiency gains and thereby have a greater incentive to cut costs.

[d]J.R. Emshwiller and K. Kranhold, "California's Power Deregulation Isn't As Open As It Looks," *Wall Street Journal* (February 17, 1998), p. B2.

U.S. Electricity Deregulation: The California Experience (Continued)

In 2000, much attention was focused on the performance of California's recently deregulated electricity market. In its third year of operation, the newly reformed electricity sector faced an exceptionally hot weather spell in May 2000, which led to electricity supply problems. Among other factors, the problem was exacerbated by a 3-year drought in the Northwest that significantly reduced the hydroelectric capacity available to the western States; the constrained capacity of transmission lines to bring more electricity into California; the reduced availability of some power plants because they had used their allotted emission allowances and because of their extended use during the previous summer; and the high cost of purchasing emission allowances, which would have allowed the plants to continue to operate.[e]

Exceptionally high natural gas prices also contributed to California's runup in electricity prices. Insufficient pipeline capacity both at the border and within the State severely limited available gas supplies, and border prices spiked to more than six times the New York Mercantile Exchange (NYMEX) price.[f] In May, the California ISO had to request industrial customers and other large users, who had agreed to reduce demand when asked, to take those steps. In June 2000, the exceptionally hot weather and a grid operational problem led to rolling blackouts in the San Francisco Bay area.[g] The Bay Area's local utility, Pacific Gas & Electric, was forced to interrupt service to 100,000 customers.

In the summer of 2000, both Pacific Gas & Electric and Southern California Edison were operating under retail rate caps that are scheduled to be in affect until April 2002 according to A.B. 1890. Customers of San Diego Gas & Electric (SDG&E), however, were the first to see rate caps removed, and their electricity bills rose sharply. In the California PX, ancillary prices reached $9,999 per megawatthour.[h] The high wholesale power prices led to concerns that power producers could be exercising market power, and SDG&E asked the Federal Energy Regulatory Commission (FERC) "to declare California markets uncompetitive and to impose [price] controls."[i] SDG&E had at the time been passing on its sharply higher purchased wholesale power costs to its retail consumers. Electricity bills in San Diego tripled.

In August, California Governor Gray Davis directed the State's Attorney General to investigate whether "possible manipulation in the wholesale electricity market" had occurred.[i] In September 2000, the governor signed legislation that would cap San Diego electricity prices for residential and small commercial users at 6.5 cents per kilowatthour—less than half the average price in August—retroactive to June 1, 2000. The governor also directed the California Energy Commission to expedite siting reviews for new power plants.[i] In August, in order to address the problem of inadequate long-term electricity capacity, the governor signed A.B. 970, accelerating the power plant approval process from 12 months to 6 months.[j]

California's electricity troubles continued to deepen toward the end of 2000 and into the beginning of 2001. In December, the price of electricity skyrocketed to 30 cents per kilowatthour.[k] With their ability to raise retail electricity prices restricted, and facing exceptionally high pool prices, Pacific Gas & Electric and Southern California Edison defaulted on hundreds of millions of dollars in debt and power bills. Together, the two utilities accumulated more than $12 billion in debt as a result of the sharp rise in California pool prices, and both utilities have seen their debt downgraded to below investment grade status.[l] On the consumer side, the retail price caps shielded electricity customers from the impacts of the market price spikes, and there was no price pressure to encourage demand reductions. In early 2001, the State experienced a series of short-duration, rolling blackouts in which more than 675,000 homes and several large industrial users lost electric power.[m]

(continued on page 128)

[e]Energy Information Administration, "The California Electricity Situation: Subsequent Events," web site www.eia.doe.gov/cneaf/electricity/california/subsequentevents.html (January 29, 2001).

[f]"California Haunted by Neglect of Infrastructure," *Natural Gas Week* (December 18, 2000), p. 11.

[g]Michael Kahn (Electricity Oversight Board) and Loretta Lynch (California Public Utilities Commission), "California's Electricity Options and Challenges: Report to Governor Gray Davis."

[h]Ancillary services are those services necessary to support the transmission of energy from resources to loads while maintaining reliable operation. They include reactive power supply, voltage support, regulation, and frequency control, among other things.

[i]"California Looks in Every Direction Seeking 'Fix' for Power Market Shock," *Electric Utility Week* (August 7, 2000), p. 1.

[j]Energy Information Administration, "Status of State Electric Industry Restructuring Activity," web site www.eia.doe.gov/cneaf/electricity/chg_str/tab5rev.html.

[k]R.L. Olson, "Power: Who is the Real Freeloader," *Los Angeles Times* (January 17, 2001), p. A13.

[l]"California's Power Crisis, A State of Gloom," *The Economist* (January 20, 2000), p. 55.

[m]D. Whitman, "California Unplugged," *U.S. News and World Report* (January 29, 2001), p. 26.

U.S. Electricity Deregulation: The California Experience (Continued)

High wholesale prices in California have contributed to higher prices in neighboring States, resulting in a regional electricity crisis that has caused several State governors to ask for wholesale price caps.[n] In December 2000, FERC capped bulk power prices at $150 per megawatthour, although both newly elected President Bush and the recently appointed Commissioner of FERC have opposed price caps.[o] Generating companies could petition for higher prices, however, if they could justify them.[p] The FERC had undertaken an investigation of California's electricity market and market structure in July 2000 as part of an investigation examining the national electricity market.

On November 1, 2000, FERC released a draft order calling for changes in California's market, recommending that the State build more power plants and invest more in transmission lines.[q] The Commission also proposed eliminating the requirement that California's major utilities buy and sell all their electricity through the pool, and recommended that they be allowed to engage in long-term forward contracts.

In December 2000, the U.S. Secretary of Energy, Bill Richardson, issued an immediate order forcing 75 power generators in western States to supply electricity to California. He further ordered that power producers sell power to California "even if they are uncertain of payment."[r] In January 2001, Governor Davis signed an emergency order allowing California's Department of Water Resources to become a temporary buyer of power, providing the agency with a spending authority of $400 million, and in February 2001 he signed a measure allowing the Department to float an estimated $10 billion in revenue bonds to finance power purchases directed at acquiring electricity through long-term contracts. The bonds are to be paid off by electricity consumers. The bill also includedsome conservation measures, requiring retailers to cut their outdoor lightning use by half or face penalties. In March 2001, the FERC ordered 10 generation companies to reimburse the California ISO $69 million for charging rates deemed not to be "just and reasonable." The reimbursement amounted to only a fraction of the $550 million sought by State officials for overcharges.[s]

Sharp price spikes are not new to pool-based electricity exchange systems. In countries that have adopted pool-based electricity trading systems, such as the United Kingdom and Australia, concerns have arisen about the connection between price spikes and market power. In the wake of California's recent experience with its electricity pool, a similar concern has arisen that suppliers may have achieved excessive market power.

Several other arguments have also been offered to explain the problems experienced by California's electricity market in 2000. Long-term underinvestment in the State's electricity sector has been cited as a contributing factor, given that its rapidly growing economy has produced sharp increases in electricity demand. It has become increasingly difficult to build new generation facilities in the State, and generation capacity additions have severely lagged far behind growth in demand since the early 1990s. The average age of a power plant in California is currently more that 30 years.[t] Indeed, operational difficulties have plagued California's electricity infrastructure over the past year. During the height of the electricity crisis several power plants were pulled out of production, and congestion constraints became apparent on the State's north-south transmission line.

[n]R. Smith, "Governors Seek Caps on Prices of Electricity," *Wall Street Journal* (February 5, 2001), p. A3.

[o]The newly appointed FERC Commissioner has spoken out against price caps. Commissioner Hebert agreed to the $150 per megawatthour price cap only after the cap's duration was shortened from 24 months to 14 months. See R. Smith, "Regulators Step In To Ease Price Shocks in California's Deregulated Power Market, *Wall Street Journal* (December 18, 2000), p. A2.

[p]R. Smith, "U.S. Panel Proposes Big Market Change To Curb California's Electricity Prices," *Wall Street Journal* (November 2, 2000), p. A3.

[q]N. Banerjee, "U.S. Proposes Change in Electricity Market," *New York Times* (November 2, 2000), p. A26.

[r]"Unpaid, California's Small Power Suppliers Begin To Shut Down," *Wall Street Journal* (February 1, 2001), p. A4; and D. Morain and N. Vogel, "U.S. Sets Rules To Ensure Electricity Sales to State Utilities," *Los Angeles Times* (December 15, 2000), p. A1.

[s]J. Kahn, "Federal Agency Orders Power Generators To Justify Prices," New York Times (March 10, 2001), p. A6.

[t]Michael Kahn (Electricity Oversight Board) and Loretta Lynch (California Public Utilities Commission), "California's Electricity Options and Challenges: Report to Governor Gray Davis."

National Grid Group, PLC, of the United Kingdom purchased New England Electric System in 2000 and reached a merger agreement with Niagara Mohawk of New York in 2001. This merger, if carried through, is expected to be valued at $3.2 billion along with the assumption of $5 billion in debt [***15***]. British Energy has formed a joint venture with PECO Energy, AmerGen, which has been responsible for some of the largest acquisitions of electricity generation assets to date.

Two electricity generation companies in the United Kingdom, National Power and PowerGen, have also acquired U.S. electricity assets. PowerGen is the United Kingdom's second largest generating company, after

National Power. In February 2000, LG&E Corporation announced its intended merger with PowerGen. The estimated value of the transaction was $3.2 billion, and the combined company will have assets of $12 billion. American National Power, the Texas-based subsidiary of National Power, currently has 9,000 megawatts of power capacity under development in the United States [***16***]. National Power is expected to have 4,000 megawatts of capacity in operation in the United States by 2004 [***17***].

Japanese and French companies have also started to invest in U.S. electricity assets. In November 1999, Tokyo Electricity Power Company and Mitsubishi Corporation each purchased a share in Orion Power Holdings. Orion is a joint venture between the investment bank, Goldman Sachs, and the Baltimore-based utility, Baltimore Gas & Electric. The Japanese company Marubeni and the French conglomerate Vivendi had taken a 30-percent interest in the U.S. independent power producer, Sithe Energies.

Regulatory Developments

At the end of 2000, more than half the States had adopted legislation or issued regulatory orders in an attempt to introduce reforms in their electricity markets [***18***]. Reforms have been most prominent in those regions with exceptionally high electricity prices, such as California and the northeastern United States. Changes in technology have also driven reform. Through the 1960s and 1970s, electricity generation grew more efficient with size, or marginal costs declined as generation units got larger. Since then, however, the trend has been for maximum efficiencies to be increasingly achieved at relatively smaller generation capacities. This development has forced a reappraisal of the idea that generation is a natural monopoly and has brought to the fore the idea that competition in generation is achievable.

States have had to address a number of issues in deregulating their electric utility markets. One issue concerned the vertical separation between the generation business and the wires (distribution and transmission) business. In recent years, much merger and acquisition activity has been driven by State-mandated asset sales in order to separate the ownership of generation assets from distribution assets. Another major concern was the issue of how to finance stranded costs.

States' efforts at encouraging utilities to shed their generation assets have increased the role of nonutility generators. Utilities sold 50,888 megawatts of capacity in 1999 to nonutility electricity providers [***19***]. These nonutility electricity providers had 167,357 megawatts of installed capacity in 1999, up from 70,254 megawatts in 1995. Nonutility generating facilities accounted for 15 percent of the market in 1999, up from 11 percent in 1998.

Mexico

Mexico has for several years debated the possibility of privatizing its electricity sector. Some progress towards privatization was made when Mexico opened up its generation market to independent power producers in 1996. In December 2000, Mexico witnessed an historic change of government with the party holding the Mexican presidency for the past 71 years (the Institutional Revolutionary Party, or PRI) relinquishing the Mexican presidency to an opposition party, the National Action Party (PAN). President Fox has pledged to submit an electricity bill which is expected to grant private investors greater latitude in investing in Mexico's electricity sector. Mexico has seen its electricity consumption grow at an annual rate of 6 percent between 1994 and 1999 [***20***].

Japan

Japan's decade-long economic malaise continues to restrain that nation's electricity consumption growth. While the U.S. economy expanded an estimated 33 percent between 1990 and 1999, Japan's economy grew by 13 percent. Japan's economic growth rate is expected to average 1.3 percent between 1999 and 2010 and 1.7 percent between 2010 and 2020. Electricity growth in Japan is expected to trail GDP growth and average 1.3 percent between 1999 and 2020.

Japan has some of the highest electricity prices in the world. As a result, the nation is currently undertaking electricity reforms in an attempt to reduce these prices. In March 2000, the retail supply sector for high-volume users (over 2 megawatts) was liberalized. Large customers were allowed for the first time to choose their electricity suppliers, and electricity suppliers were allowed to sell outside of their traditional franchised territories.

Western Europe

In 1996, the 15 members of the European Union adopted its electricity directive. The directive became effective in February 1997. The goal of the directive was the eventual establishment of a single European electricity market. A single market would foster competition and reduce the price of electricity to consumers. The electricity directive called for the member nations to open at least 26 percent of their national markets to competition by February 1999.[23] By the year 2000, the signatories were expected to expand this share to 30 percent and to 35 percent by 2003. The directive establishes uniform rules for all aspects of electricity supply and calls for the unbundling of separate energy services: generation, transmission, and distribution. The purpose behind unbundling is to

[23]Belgium and Ireland were given an additional two year grace period to catch up with other European Union members to abide by its electricity directive. Belgium chose to wave its grace period. Greece was given three years.

avoid discrimination and cross-subsidization. The directive allows for a choice between negotiated third-party access and a single-buyer model.

Electricity is a "network" industry. European electricity deregulation has taken place in the context of a general effort at deregulating network industries, such as natural gas, telecommunications, rail, trucking, postal services, airlines, water, etc. The purpose of the EU electricity directive was to reduce the price of electricity through greater competition and to move away from monopoly power to a freer market. European electricity has long been characterized by national monopolies with sole domain over home territories.

An important element of the EU electricity directive is the requirement that electricity services become unbundled. This has had a marked impact upon the way companies have begun to offer services and on the way the industry is structured. Unbundling has separated generation services from transmission and distribution services. Unbundling has also promoted the growing importance of marketing and trading of electricity as separate services.

Germany has been the most aggressive of the EU nations in implementing the electricity directive. Instead of phasing in competition over a number of years as called for in the directive, the German government opened up its electricity market to unrestricted competition in 1998. The resulting sharp decline in German electricity prices was an unexpected benefit from this decision; German industrial electricity rates, once among the highest in Europe, are now lower than in any Western European country except hydro-intensive Norway and Finland [***21***]. Between 1996 and 1999, German electricity prices to industrial consumers are estimated to have fallen 29 percent, while residential consumers have seen a 14-percent reduction in prices [***22***]. In 1999, German industrial electricity prices averaged 6.28 cents per kilowatthour (in 1998 dollars), as compared with 8.87 cents per kilowatthour in 1996.

In contrast to Germany, France has only reluctantly accepted the requirements under the EU electricity directive. In June 2000, the European Commission took legal actions against the French government for its failing to incorporate the directive into French law. Germany's government has threatened to bar imports of electricity from any country which fails to abide by the directive's call for the opening of national electricity markets to competition. Electricite de France is the largest utility in the world and has exclusive control over the French electricity market. Electricite de France has promoted the idea of a single-buyer model over the open-access system.

Today the most open electricity markets in Europe exist in the United Kingdom, the Netherlands and Scandinavia, followed by Spain and Italy. Largely due to political factors and the relative strength of national utilities, Portugal, France, and Belgium have lagged the other European Union member countries in opening up their electricity sectors to competition.

Eastern Europe and the Former Soviet Union

The FSU and much of Eastern Europe suffer from an antiquated electricity generation and transmission infrastructure. Although electricity demand is expected to be 47 percent higher in 2020 than in 1999, the region is not expected to see much in the way of capacity expansion, although the fuel mix will involve a movement away from coal to natural gas. Rather, future investment will be directed in large part to upgrades, in efforts to bring the region's electricity industry up to the standards of those in the industrialized nations.

Developing Asia

Of all world regions, Asia is expected to show the most robust rate of growth in electricity consumption over the forecast period. Electricity demand in developing Asian nations is expected to grow by an average of 4.5 percent per year between 1999 and 2020. Developing Asia accounted for 18 percent of worldwide electricity consumption in 1999, and by 2020 it is expected to account for 26 percent.

Coal, which supplied 54 percent of the fuel used to generate electricity in developing Asia in 1999, is expected to maintain that level by and large, declining only slightly to 52 percent in 2020. In the rapidly growing Asian energy market, coal consumption in absolute terms is expected to more than double over the same period. Nuclear, renewables, and oil are expected to lose market share. Natural gas is the only fuel that is expected to increase its share of the Asian electricity market, from 9 percent in 1999 to 11 percent in 2020.

The financial and economic crisis that started in Thailand and quickly spread to other economies of Southeast Asia in mid-1997 has eased considerably. By 1999, most Asian nations began to show positive rates of economic growth.

Private investment in developing Asian power projects has slowed considerably, after several years of rapid growth. The reduction can be attributed in part to the 1997-1999 economic recession; however, the slowing trend has continued well into the region's economic recovery. Most of the investment now occurring is directed toward adding to the region's generation capacity. Among the developing nations, the decision to sell off complete electric utilities wholesale to private (including foreign) investors has largely been a South American phenomena; developing Asian nations have been much slower than the nations of South America to privatize national electricity assets.

Privatization efforts in developing Asia have consisted largely of allowing private participation in new generation (greenfield) investments. Until recently the Philippines appeared ready to depart from the trend by privatizing its state-owned utility, Napocar; but the recent ouster of the Estrada government has delayed the Napocar privatization plan despite the earlier commitments the government had made.

In several nations of developing Asia, electricity pools or transmission interlinkages are being developed to provide better capacity management and to facilitate trade in excess power. China, Indonesia, South Korea, the Philippines, and Thailand have announced plans to develop national electricity pools. In the process of liberalizing its electricity market, South Korea intends to begin a power pool in 2003 [***23***]. The initial phase of South Korea's electricity reform efforts also intends to allow industrial users to choose their electricity suppliers. Similarly, in an effort to induce more competition in electricity generation, the Chinese government is promoting an electricity pool over the formerly used bilateral contract arrangements.

China

Overall, China is expected to add more to its electricity generation capacity between 1999 and 2020 than any other nation in the world—for example, more than twice the capacity additions projected for the United States. China is far and away developing Asia's largest economy, accounting for roughly one-third of the region's economic activity. China has also had the region's fastest rate of economic growth in recent years. Although its rate of economic growth has slowed over the past year or two, the Chinese economy was not dramatically affected by Asia's economic crisis.

China's current 277,000 megawatts of installed electricity capacity is second only to that of the United States [***24***]. Electricity consumption is expected to grow at a 5.5-percent annual rate over the 1999-2020 period. China's fast pace of future electricity consumption growth is due in part to its current underdeveloped electricity sector. Per capita consumption of electricity is currently one-twentieth of that in the United States.

Coal currently accounts for 65 percent of China's electricity fuels market, and its share is expected to decline slightly through 2020. Clearly, however, if the Kyoto Climate Change Protocol or a successor policy with similar provisions is enacted, China could become an ideal candidate for joint implementation agreements to mitigate growth in carbon emissions.

China has the world's second largest coal reserves and is both the world's largest producer and consumer of coal. However, its coal reserves generally lie in the interior region of the country, far away from coastal economic activity. China is currently promoting the building of minemouth electricity plants rather than constructing additional rail lines to transport coal to eastern regions [***25***].

After coal, renewables account for the second largest share of China's electricity market, with a 26-percent overall share in 1999. China's consumption of renewable energy (mostly hydroelectricity) is expected to double between 1999 and 2010 and to increase its share of China's total electricity market. By the time it becomes fully operational in 2009, the $30 billion Three Gorges Dam will have an installed capacity of 18,200 megawatts of power. When it is completed, Three Gorges will be the largest dam in the world, five times wider than the Hoover Dam in the United States [***26***]. After 2010, growth in renewable energy is expected to moderate, and its share of the electricity market is expected to start to fall.

Although nuclear power currently accounts for a very small share of China's electricity market (approximately 2 percent in 1999), the Chinese government has an ambitious plan for additional nuclear power over the next two decades. By the end of the forecast period, nuclear power plants are expected to supply nearly 6 percent of the electricity used in China.

During the late 1980s, China implemented electricity reforms aimed at reducing government's managerial role in electricity supply [***27***]. The government allowed for a "fuel cost rider" in 1987, permitting generation companies to pass on higher fuel input costs to consumers [***28***]. More recently, price reforms have been undertaken to increase the attractiveness of investments in China's electricity sector, which had periodically suffered from capacity shortages. One such reform was implemented in 1996 during the financing negotiations surrounding the Laiban B project (a 700-megawatt coal plant). In awarding the contract for the financing of Laiban B, rather than negotiating an allowable rate of return, China's government chose to auction off the project to bidders offering the lowest tariff per kilowatt. Before the Laiban B deal, foreign investors had often criticized China's allowable rates of return on electricity investment for being too low.

Price reform is another means by which the Chinese government has attempted to attract private capital investment in electricity. In 1998, China deregulated electricity prices for rural areas [***29***]. In 1999, China's government announced plans to allow generators to bid competitively for access to power networks [***30***].

India

Second only to China among developing countries in terms of population and economic activity, India is expected to increase its consumption of electricity at a 3.9-percent annual rate over the forecast period. Heavy reliance on coal as an electricity fuel is expected to lessen somewhat, with coal's share of the market declining from 76 percent in 1999 to 65 percent in 2020. Natural gas and nuclear power will largely make up for coal's lost share. In 2020, natural gas is expected to account for 11 percent of India's electricity fuels market, up from 5 percent in 1999. The nuclear share is expected to increase from 2 percent in 1999 to 6 percent in 2020.

As in China, foreign investment will play a key role in the financing of India's power sector expansion. The Indian government opened up the power sector to private investment in 1991 with the passage of an amendment to the 1948 Electricity Supply Act that allowed for the construction of independent power projects.

In December 1996, the Indian central government announced its policy for electricity development [***31***]. Called the "Common Minimum National Plan for Power," the policy intends to restructure and corporatize the state electricity boards, to allow them greater autonomy, and to allow them to operate along commercial lines. The plan also attempts to ease the approval process for private power projects selected for competitive bidding by the central government. In June 1998, the central government went several steps further and eased its rules for foreign investment in the power sector. Automatic approval is to be given to projects costing in excess of 15 billion rupees (about $355 million) that involve 100 percent foreign equity.

The removal of subsidies flowing from urban electricity consumers to rural users has been a serious issue as India has undertaken electricity reform. The subsidies have been substantial, and their removal would in some Indian regions lead to sizable increases in rural electricity rates. The Indian government's Electricity Regulatory Commission issued an ordinance in 1998 directed at rationalizing electricity tariffs and subsidy policies. Under the new ordinance, the state regulatory entities would have the authority to remove rural subsidies [***32***].

India is also in dire need of an upgrade of its transmission system. Currently, as much as 20 percent of India's electricity is lost [***33***], much of it through "nontechnical" losses from theft or leakages and from errors in meter reading, accounting, and billing procedures [***34***].

Other Developing Asia

Developing Asian nations other than China and India also are expected to see rapid growth in electricity consumption over the coming years. Although in 1997 and 1998 many Asian economies slipped into recession—some for the first time in recent memory—by the end of 1999 most were showing signs of strong economic recovery. Electricity consumption for the collective region is expected to grow at a 3.3-percent annual rate between 1999 and 2020.

The Asian economic crisis took a particularly heavy toll in Thailand, where electricity demand has not yet returned to its pre-crisis rate of growth [***35***]. The Electricity Generating Authority of Thailand (EGAT), Thailand's state-owned electricity company, has postponed or delayed a number of projects, including two 300-megawatt plants at Ratchaburi. Ratchaburi eventually is expected to have 3,200 megawatts of generating capacity, and it is expected to be privatized by the Thai government [***36***]. Thailand's electricity reform plan, which also involves the creation of a national pool, calls for the unbundling of the electricity industry's generation, transmission, and distribution components before they are privatized.

In 1999, the region as a whole depended most heavily on coal (which supplied 29 percent of electricity) and oil (21 percent). No other world region outside the Middle East currently depends so heavily on oil as a source of electricity generation, and oil's share in the region is not expected to change over the forecast period. Renewable energy use in other developing Asia is projected to decline in importance, falling to 15 percent of the electricity fuels market by 2020 from 22 percent in 1999. Little additional nuclear capacity is expected to be built in other developing Asia, with the exceptions of Taiwan and South Korea.

Natural gas is expected to supplant oil and renewables in large measure. From 22 percent of the region's electricity fuels market in 1999, the natural gas share is expected to increase to 27 percent by 2020. In the near term, growth in natural-gas-fired generation is hampered by a lack of transportation infrastructure. For instance, virtually all of Taiwan's natural gas demand is met by imported LNG. In the long term, natural gas supplies might arrive via pipelines connecting the Caspian sea region with China and perhaps Japan, and natural gas pipelines may some day connect gas reserves in Indonesia to electric power plants in other Southeast Asian nations.

Africa

South Africa accounts for almost one-half of the electricity generated on the African continent, and South Africa, Egypt, Algeria, Libya, and Morocco together account for nearly three-quarters of the continent's total electricity production. Africa as a whole is expected to see electricity consumption grow at a 3.8-percent annual rate over the 1999-2020 projection period. No other region has as little access to electric power as Africa. Coal provided roughly half of the region's electricity production in 1999, and in 2020 its share is expected to be 36 percent.

Several African countries have recently opened their electricity sectors to private investment. In Morocco, the 1,356-megawatt Jorf Lasfar power project was completed and began operating in February 2001 [***37***]. The $1.5 billion coal-fired power plant is the largest independent power plant in Africa and the Middle East to date. Located on the Atlantic coast about 78 miles southwest of Casablanca, the plant now generates more than one-half of Morocco's total electricity supply and accounts for about 35 percent of its installed capacity. Jorf Lasfar is jointly owned by CMS Energy and the Swedish / Swiss company, Asea Brown Boveri. Electricity from the project is sold to the country's state-owned utility, Office Nationale de l'Ectricite (ONE) under a 30-year purchase agreement. Egypt's cabinet in 1996 approved the startup of a BOT program involving 1,600 megawatts of power [***38***].

In the Ivory Coast, the government launched plans for privatizing many of its public entities in 1990 [***39***], beginning with the national electric utility, Compagnie Electricite Ivoirienne (CIE), which is now jointly owned by two French companies, Electricite de France (EDF) and Saur-Bouygues. In 1993, the two companies began the joint development of Compagnie Ivoirienne de Production d'Electricite (CIPREL), one of the first independent power projects in sub-Saharan Africa. The gas-fired plant began providing electricity to the country's national grid in 1997 with an initial capacity of 100 megawatts, which was expanded to 210 megawatts in 1998. The country has seen growing interest in development of its electricity sector in recent years. In addition to EDF and Saur-Bouygues, Asea Brown Boveri began work as part of the Cinergy consortium (along with EDF and Industrial Promotion Services, an affiliate of the Aga Khan Fund for Economic Development) on several thermal power projects in the Ivory Coast. Moreover, French electricity and transportation company Clemessy has been contracted to electrify 100 Ivory Coast villages, which is scheduled for completion by the second quarter of 2001.

Nigeria is also attempting to encourage foreign participation in electricity generation. In late 1998, Mobil, one of the largest producers of oil in Nigeria, announced that it had contracted to build a 350-megawatt natural-gas-fired independent power project in Nigeria [***40***]. Early in 2000, Nigeria gave ExxonMobil permission to build and operate a 350-megawatt gas-fired power station in the Niger Delta area [***41***]. In June 2000, the country signed an agreement with Enron for a 270-megawatt electricity project in Lagos. Nigeria is also negotiating with Shell and Texaco to establish private power plants that could provide an emergency electricity supply. The country has faced serious electricity shortages for the past several years because of declining generation from domestic power plants.

In March 1999, Senegal announced the privatization of its electric power industry. In that same month, the Senegalese government sold 34 percent of the shares of the Société Nationale d'Électricité (SÉNÉLEC), to the French-Canadian consortium, Hydro-Quebec-International-ELYO (HQI-ELYO) for $69 million (U.S. dollars) [***42***]. As a result, the HQI-ELYO consortium became responsible for managing all electricity production, transmission, and distribution activities associated with SÉNÉLEC.

Algeria's Parliament is currently debating legislation that would end the monopoly held over power production by the Algerian state utility, Sonelgaz, by allowing independent power production [***43***].

Middle East

Almost two-thirds of the Middle East region's economic output is accounted for by Iran and Saudi Arabia, along with half the region's electricity consumption. Iran is the most populous country in the Middle East, and Saudi Arabia has one of the highest per capita incomes. Other large users of electricity in the Middle East include Israel, Iraq, and Kuwait. Largely as a result of growth in the region's dominant economies, electricity consumption in the Middle East is expected to grow at a 3.4-percent annual rate over the projection period.

The Middle East depends heavily on petroleum to fuel its electricity generation. In 1999, oil-fired generation accounted for 35 percent of all electricity produced and natural gas 41 percent. That level of dependence is expected to continue over the forecast period. Over the next few years, Iran is expected to enter the league of nations owning nuclear power reactors, and by 2020 nuclear power is expected to account for 1 percent of the region's electricity production.

A five-country electricity transmission network is being developed by Egypt, Iraq, Jordan, Syria, and Turkey. The project, which is expected to cost $450 million, would save the countries an estimated $2 billion a year by allowing them to share excess capacity at times of peak demand [***44***]. In March 2001, Jordan and Syria are expected to inaugurate the Syrian / Jordan component of the regional electricity grid. Links are expected to be established between Syria and Turkey by the end of 2001 and between Lebanon and Syria by 2002 [***45***].

Among Middle Eastern nations, Israel took a step towards privatization recently. In 1996, Israel's parliament passed a new electricity law allowing the Energy

Minister to grant permits to independent power producers [*46*]. In keeping with the privatization effort, the Israel Electric Company (IEC), Israel's national utility, has been directed by the Energy Minister to purchase 900 megawatts of power from independent power producers by 2005 [*47*].

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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.

Transportation fuel use is expected to grow substantially over the next two decades, despite oil prices that hit 10-year highs in 2000. The relatively immature transportation sectors in much of the developing world are expected to expand rapidly as the economies of developing nations become more industrialized. In the reference case of the *International Energy Outlook 2001* (*IEO2001*), energy use for transportation is projected to increase by 4.8 percent per year in the developing world, compared with average annual increases of 1.6 percent in 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 (Table 22).

The high world oil prices of 2000 have had little effect on demand for transportation fuels, so far. Oil prices recovered from their 1998 record lows throughout 1999 and surpassed $30 per barrel in the fourth quarter of 2000. The efforts of the Organization of Petroleum Exporting Countries (OPEC) to bring prices down to what it considers the optimal range of $22 to $28 per barrel by adding 700 thousand barrels per day to production in July and another 800 thousand in September were largely unsuccessful [***1***].

Some consumers in the United States, especially those in the Midwest and in California, saw summer motor gasoline prices surpass $2 per gallon—the result of a combination of high world oil prices, supply problems related to pipeline disruptions, and the higher refinery costs of new Federal regulations on motor gasoline. High gasoline prices focused consumer attention on the issue in the atmosphere of a U.S. presidential election year. Political discussions included suggestions for temporarily reducing or removing Federal motor gasoline taxes, but with lower prices after the summer peak the issue was dropped.

In contrast, in Western Europe, the combination of high world oil prices and heavy government taxes provoked angry protests among the region's ordinarily subdued petrol users. Consumers in Europe typically accept increases in motor fuel prices because the prices are already high relative to U.S. levels. Taxes often make up more than 50 percent of the total fuel cost in Europe. In September 2000, with $35 per barrel (and higher) oil prices stubbornly hanging on, French farmers and freight carriers waged a 3-week protest against the high costs of fuel, and eventually they were able to persuade the French government to reduce some motor gasoline taxes by 15 percent. Strikes quickly spread to other

Table 22. 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**	**3!**	**35**	**2.0**	**1.6**
North America	13	15	19	23	2.1	2.0
Western Europe	6	7	8	9	1.8	1.0
Industrialized Asia	2	3	3	3	2.4	1.0
EE/FSU	**3**	**2**	**3**	**4**	**-5.0**	**2.8**
Developing	**7**	**11**	**18**	**29**	**5.2**	**4.8**
Asia	3	6	10	16	6.8	5.1
Middle East	1	2	3	5	4.1	4.8
Africa	1	1	2	2	3.4	3.0
Central and South America	2	2	4	6	3.4	4.6
Total World	**31**	**38**	**51**	**68**	**2.2**	**2.8**

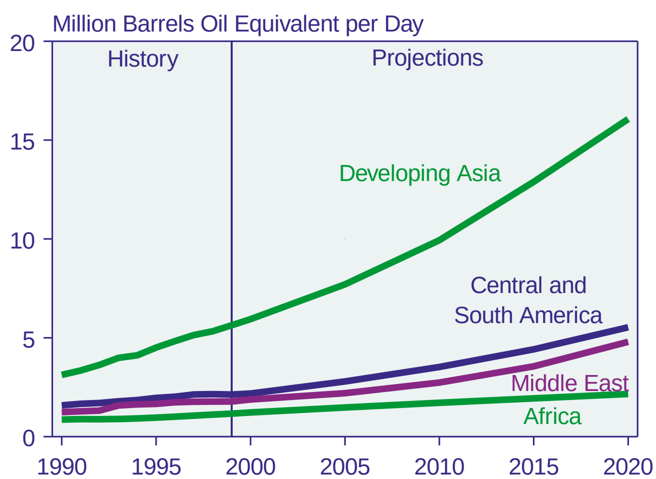
Sources: **History:** Derived from Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, World Energy Projection System (2001).

Western European countries, including Belgium, Germany, Italy, the Netherlands, Poland, and the United Kingdom, and strikes were threatened in Spain, Sweden, Greece, and Ireland.

High world oil prices also caused concern in the developing world, particularly in the recently recovering economies of southeast Asia, where further recovery was threatened by the sustained high world oil prices. In Indonesia—the last southeast Asian economy to show some recovery from the 1997-1999 recession—efforts to raise gasoline prices to reflect the higher world oil prices were met by demonstrations from consumers after the first day of the rate increases. Oil demand in Asia remained strong during 2000, but there are growing fears that high petroleum product costs will weaken demand growth, drive up inflation, and stop the region's economic expansion in the short run.

The mid-term forecast for the transportation sectors of the countries in southeast Asia is one of strong growth. The *IEO2001* reference case projects robust growth in transportation energy use in developing Asia, by 5.1 percent per year between 1999 and 2020. Rapid growth is also projected for the Middle East and for Central and South America, at 4.8 and 4.6 percent per year, respectively (Figure 84). Much of the growth is expected to be in road use, a combination of freight movement and personal motor vehicle ownership. Personal vehicle ownership is seen as a symbol of emerging prosperity in many of the urban centers of the developing world, and annual car sales have grown by double-digit percentages in many Asian countries.

Figure 84. Transportation Energy Consumption in the Developing World by Region, 1990-2020



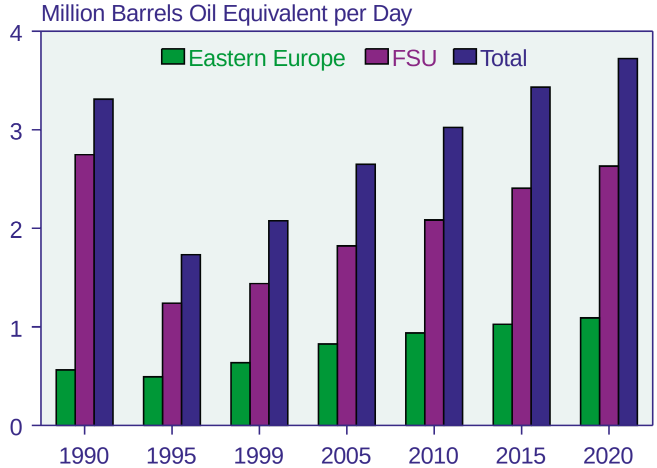
Sources: **History:** Derived from Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, World Energy Projection System (2001).

There are many factors that might hinder the growth of the transportation sector in the developing world. For example, many of the economies with the greatest projected growth also have the most immature transportation infrastructures. In major cities such as Mumbai (formerly Bombay), Bangkok, Mexico City, and Shanghai, congestion is a major problem that causes high levels of air pollution and increasing instances of respiratory disease. Indeed, there is increasing interest in the development of vehicle fleets that are run on fuels other than petroleum, such as natural gas, to address pollution problems (see box on page 140). In addition to pollution issues, many countries, such as India and China, have not established major highways (along with gasoline stations and other necessary amenities) to connect cities, making it difficult to travel by automobile. In order for motorization levels to continue to grow apace over the forecast period, developing nations will have to invest substantially to improve transportation networks and address increasing congestion on the roads of major urban centers.

In the former Soviet Union (FSU), high world oil prices have helped to boost the economies of the oil-exporting republics, notably Russia, the region's largest economy. The August 1998 devaluation of the Russian ruble resulted in a sharp reduction in imports, and domestic production subsequently increased to meet consumer needs. Industrial production increased by 8.1 percent in 1999, by 11.2 percent in the first quarter of 2000, and by 8.5 percent in the second quarter [***2***]. The improved economic situation in Russia was accompanied by similar growth in its transportation sector. Freight transport in the country grew by a reported 5.2 percent in 1999 (rail 18.1 percent, air 13.8 percent, and road 3.3 percent) [***3***]. In the *IEO2001* reference case, oil use in the transportation sector is expected to continue to recover in the FSU, growing at an average annual rate of 2.9 percent per year and nearly recovering to the region's Soviet-era consumption levels by 2020 (Figure 85).

Although fuel for road use remains the dominant form of transportation sector energy consumption worldwide, the fastest-growing mode of transportation energy use in the *IEO2001* reference case forecast is air (Figure 86). *IEO2001* projects that air travel will increase by 4.2 percent per year worldwide over the 21-year projection period, compared with projected average annual growth rates of 2.9 percent for road energy use and 1.1 percent for "other" transportation energy use (rail, inland water, marine bunker, and pipeline transport). The forecast is based on the expectation that as economic expansion takes hold in the developing countries, their standards of living will rise and air travel for both business and leisure will increase. Substantial investment will be required, particularly in the developing world, to

Figure 85. Transportation Energy Consumption in Eastern Europe and the Former Soviet Union, 1990-2020



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

improve and expand airport infrastructures to accommodate the expected growth in demand for air travel.

Regional Activity

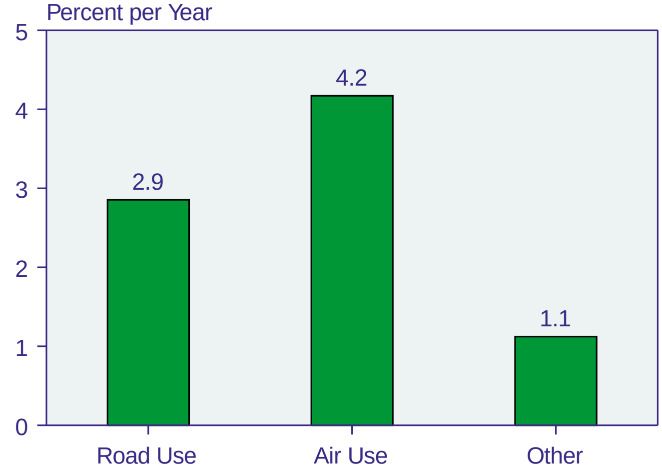
North America

North America currently accounts for about 40 percent of the energy consumed for transportation worldwide, but its share is projected to decline to about 34 percent in 2020 as the transportation sectors of emerging economies expand (Figure 87). Geographically widespread, consumers in the United States and Canada use personal motor vehicles to commute and travel greater distances than their counterparts in Western Europe and Japan, where mass transit networks are often well-established in major urban areas. Mexico's transportation energy use expanded by an average annual rate of 5.0 percent between 1980 and 1999, compared with 1.3 percent per year in the United States and 0.8 percent per year in Canada. Mexico's transportation sector is projected to continue to grow at the rapid pace of 5.2 percent per year through 2020 (Figure 88).

United States

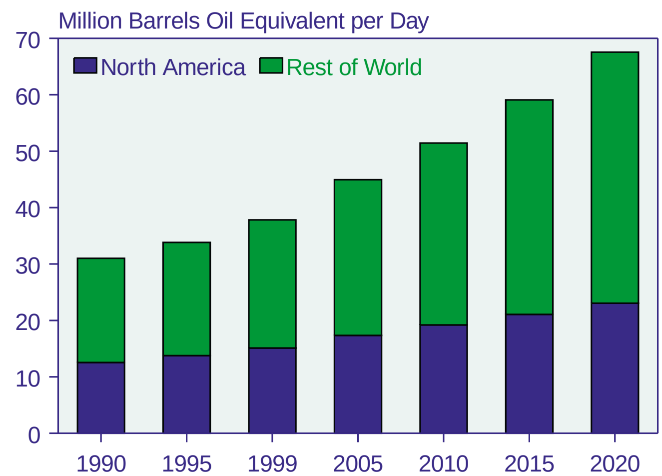
In the United States, transportation sector energy consumption is projected to increase at an average annual rate of 1.8 percent from 1999 to 2020. Growth in U.S. transportation sector energy demand averaged 2.0 percent per year during the 1970s but was slowed in the 1980s by rising fuel prices and the implementation of Federal vehicle efficiency standards. Average vehicle fuel efficiency increased by an unprecedented 2.1 percent per year during the 1980s; however, a slower rate of improvement is expected in the forecast, despite

Figure 86. Projected Annual Growth in World Transportation Energy Consumption by Mode, 1999-2020



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

Figure 87. Transportation Energy Consumption in North America and the Rest of the World, 1990-2020



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

expectations for technological advances such as gasoline fuel cells, direct fuel injection, and electric hybrids for both gasoline and diesel engines. Fuel efficiency standards for U.S. light-duty vehicles are expected to remain at current levels, and relatively low world oil prices and higher personal incomes are expected to increase consumer demand for larger and more powerful vehicles. The average fuel economy of the light-duty fleet is projected to grow from 24.2 miles per gallon in 1999 to 28.0 miles per gallon in 2020.

Natural Gas Vehicles: Worldwide Status

Natural-gas-fueled vehicles are not a new technology, having been in use since the 1930s and accounting for more than a million of the motor vehicles on the road today worldwide.[a] More than 100,000 natural gas vehicles (NGVs) are operating in the United States alone; however, this is not to suggest that NGVs make up a substantial portion of the American automotive fleet. The entire highway vehicle fleet of the United States was 212 million in 1997, and NGVs accounted for less than 0.1 percent of the country's total vehicle population.[b]

Interest in expanding the NGV fleet is growing in many parts of the world. Concerns over the pollutants released by gasoline- and diesel-fueled vehicles has helped NGVs gain momentum, and many of the new emissions standards that have recently been enacted in the United States, Canada, and Europe may increase the penetration of NGVs. For instance, in December 2000, President Clinton approved a proposal by the U.S. Environmental Protection Agency (EPA) to reduce substantially the amounts of sulfur and nitrogen oxide released by heavy-duty vehicles.[c] This followed the Tier 2 Motor Vehicle Emissions Standards and Gasoline Sulfur Control Requirements finalized by the EPA earlier in 2000, tightening emissions standards for passenger cars and light-duty trucks, minivans, and sport utility vehicles.

Canada announced in May 2000 that it would launch a national program to study measures for reducing pollution from motor vehicles with the intention to "meet or exceed the new standards that the United States will have in place beginning with the 2004 model year and culminating with the 2009 model year."[d] Similarly, the European Union (EU) passed its Auto Oil I Programme in 1997, which eliminated the use of leaded fuel by EU member countries on January 1, 2000 (except for Spain, Italy, Greece, and the French Territories, for which extensions were granted until 2002) and issued limits on sulfur, benzene, and aromatics.[e] The EU is already working on an Auto Oil II Programme, which will further tighten motor vehicle emissions standards.[f]

There are two ways in which natural gas is currently used as a motor vehicle fuel: compressed natural gas (CNG) and liquefied natural gas (LNG). CNG is the most common form of natural gas use as an alternative fuel, although there is a growing market for use of LNG in heavy-duty vehicles. The basic difference between CNG and LNG is energy density; the liquid form of the fuel carries more energy per pound than the gaseous form.[g] In the United States, an estimated 101,991 CNG vehicles and 1,682 LNG vehicles were operating in 2000.[h] In Canada, nearly 40,000 NGVs operate with a network of 125 public fueling stations.[i]

In most parts of the world, NGVs are introduced to replace buses and other public vehicle fleets, as well as taxi fleets. This has become increasingly popular in European countries where there is a concern about air quality in congested urban areas with well-established mass transit. It is also increasingly true for cities like Mumbai and Mexico City, both of which have struggled to control worsening air pollution problems. Mexico, however, has only two CNG service stations, although there are plans to increase the number to 30 before 2003.[j] Mexico hopes to increase the penetration of NGVs from 2,000 in 2000 to 35,000 to 50,000 vehicles over the next few years. The Mexican Regulatory Commission of Energy estimates that it will be able to increase the number of NGVs to 100,000 by 2008.

In Europe, the penetration of NGVs has been increasing rapidly. The EU's four largest natural-gas-consuming members, the United Kingdom, Germany, France, and Italy, are all introducing new incentives for CNG-fueled vehicles.[k] Germany offers a low tax on CNG, and the government is committed to maintaining the low tax rate until 2009. The tax on CNG is only 15 percent of the service station price of DM 1.10 per kilogram (equivalent to paying about DM 0.75 per liter for the same amount of motor gasoline, whereas the current price of motor gasoline is DM 1.85 per liter). The tax benefit for using CNG will be even more attractive in 2003, when a new ecological tax is scheduled to be levied on petroleum fuels.

(continued on page 141)

[a]Ford Motor Company, "Natural Gas Vehicles," web site www.ford.com (2000).

[b]U.S. Department of Transportation, Bureau of Transportation Statistics, *Transportation Statistics Annual Report 1999*, BTS99-03 (Washington, DC, 1999), web site www.bts.gov.

[c]D. Jehl, "New Rules To Cut Diesel Emissions," *The New York Times on the Web*, web site www.nytimes.com (December 21, 2000).

[d]Environment Canada Press Release, "Environment Minister David Anderson Announces Immediate and Long Term Actions To Bring Cleaner Air to Canadians," web site www.ec.gc.ca (May 19, 2000).

[e]Commission of the European Communities, "Guide to the Approximation of European Union Environmental Legislation: The Auto-Oil Programme" (August 25, 1997).

[f]Standard & Poor's, *World Energy Service: European Outlook, Volume I, 1999* (Lexington, MA, 1999), pp. 5-6.

[g]NGV.org, "Information: Natural Gas as a Vehicle Fuel," web site www.ngv.org (2000).

[h]Energy Information Administration, *Alternatives to Traditional Transportation Fuels 1998* (Washington, DC, 2000), web site www.eia.doe.gov.

[i]Natural Gas Vehicle Coalition, "Questions and Answers About Natural Gas Vehicles: Where Are NGVs Used Now?" web site www.ngvc.org / qa.html (no date).

[j]"Bid To Beat Mexico Smog Has NGV Chief Fuming," *Financial Times: International Gas Report*, No. 411 (November 10, 2000), pp. 7-8.

[k]"NGVs—Moving Up a Gear," *Financial Times: International Gas Report*, No. 413 / 14 (December 8, 2000), pp. 34-35.

Natural Gas Vehicles: Worldwide Status (Continued)

France is also trying to expand its NGV fleet. The country currently has 4,500 NGVs operating. In November 1999, state-run Gaz de France joined with PSA Peugeot Citroen, Renault, and Union Francaise des Industries Petrolieres to promote the NGV market, and Gaz de France has created a subsidiary, GNVert, whose purpose it is to develop a network of CNG stations along the country's road network. France has already managed to introduce CNG-fueled buses in half of its cities with populations over 200,000, and another 500 CNG buses are on order.

The United Kingdom has fewer NGVs operating than does France, only 835 and most are buses and garbage trucks.[k] The government is promoting NGVs through the 1995/1996 Powershift Programme, under which subsidies between 40 and 75 percent are offered for conversions of vehicles to CNG or liquefied petroleum gas (LPG). Funding for the project was recently tripled to about $15 million. The primary focus of the program has been on LPG use, which is growing at a rapid pace in the United Kingdom, and LPG-fueled vehicles are expected to reach 33,000 by the end of 2001.

Italy has the greatest number of NGVs in Western Europe, with some 345,000 vehicles currently operating.[l] It also has a well-established infrastructure with 340 service stations that can supply consumers with CNG. Italian natural gas supplier, Snam, has ambitious plans to expand the CNG infrastructure by doubling the distribution network and is also working with Fiat in the development of NGVs.[k] CNG service stations are expected to reach 600 by 2005.[l]

Outside the industrialized world, the potential market for NGVs could be very lucrative. In Argentina, the NGV stock increased from a few hundred in 1990 to about 600,000 in 2000, supported by 850 CNG service stations.[k] Low taxes on CNG have helped support the growth; CNG is sold for between 30 and 35 cents per liter, less than one-third the price of motor gasoline (currently about $1.10 per liter).

In Egypt, the NGV market has increased from nearly zero in 1997 to an estimated 20,000 in 2000—with most of the operating vehicles in Cairo. The supporting infrastructure for CNG has increased apace, with up to 30 public stations already operating. The Egyptian government is requiring all taxis and micro-buses to convert to CNG within a 3-year period. Even Russia has more than 200,000 NGVs operating with plans to convert another 1 million vehicles by 2010.[i]

India has committed to creating a major fleet of CNG-fueled public transport buses in Delhi, where the state government will invest $48.1 million to buy 1,100 CNG buses and will convert another 1,000 diesel-fueled buses to CNG engines.[m] An order for 1,500 CNG buses has already been placed, in part as a response to the Indian Supreme Court deadline of March 31, 2001, for Delhi to phase out all diesel-run buses in an effort to reduce air pollution. Delhi has already established 50 CNG service stations, and there are another 20 operating in Mumbai.[n] Overall, India currently has 25,000 vehicles already converted from diesel to CNG.

The major drawback for establishing a strong NGV program is lack of infrastructure. For example, the firm Gas Natural launched a program to introduce NGVs in Bogota, Colombia, but thus far there are only 110 motorists using the gas-fueled cars and only two service stations available to them.[o] The company hopes to expand the number of service stations to eight within a year's time, but the current lack of infrastructure tends to retard expansion of the NGV fleet.

One way in which countries increase their NGV fleets is through conversions of motor-gasoline-fueled cars. In Argentina, for example, vehicle conversions from motor gasoline to natural gas are averaging around 6,000 per month.[n] Vehicle conversion costs vary according to the size of the engine (typical sedans can be converted for around $4,000 excluding labor, but the conversion costs for heavy-duty engines, trucks, and buses are between $30,000 and $50,000 because of the number of cylinders needed to obtain the desired travel range of the vehicle).[p] New light-duty NGVs can cost as much as $6,000 over the price of conventional gasoline and diesel vehicles.

[l]"Methane Motors On Slowly," *Financial Times: International Gas Report*, No. 408 (September 29, 2000), pp. 10-11.

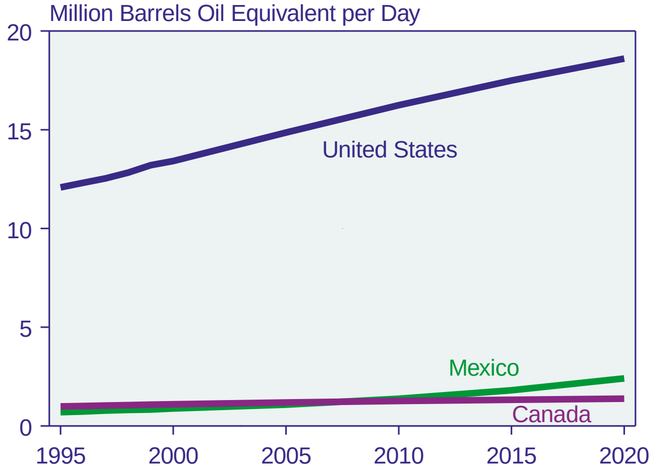
[m]"Delhi in CNG Bus Push," *Financial Times: International Gas Report*, No. 412 (November 24, 2000), p. 28.

[n]P. Hamling, "NGVs—Bridging the Gap to a Hydrogen Future," *Financial Times: International Gas Report*, No. 411 (November 10, 2000), pp. 34-38.

[o]"Colombians Try Natural Gas Cars," *The Oil Daily*, Vol. 50, No. 108 (June 6, 2000), p. 7.

[p]International Association for Natural Gas Vehicles Online, "NGV FAQs: How Much Do NGVs Cost?" web site www.iangv.org/html/sources/qa.html (December 2, 2000).

Figure 88. Transportation Energy Consumption in North America by Region, 1995-2020



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

Petroleum products are expected to continue to dominate transportation energy use in the United States. Motor gasoline consumption is projected to increase by 1.4 percent per year between 1999 and 2020, accounting for more than half the fuel use in the transportation sector in 2020 [***4***]. At the end of the forecast, alternative fuel use is projected to contribute about 203 thousand barrels oil equivalent per day, or about 2.1 percent of all light-duty vehicle fuel consumption, in response to current environmental and energy legislation intended to reduce oil use.[24] Low gasoline prices and slower fuel efficiency gains in conventional light-duty vehicles (cars, vans, pickup trucks, and sport utility vehicles) are projected to result in a stable market share for gasoline over the forecast horizon.

Air travel is also projected to increase in the forecast, but at the same time, new aircraft fuel efficiencies are expected to increase by more than 17 percent from 1999 levels by 2020. Ultra-high-bypass engine technology alone may increase fuel efficiency by as much as 15 percent, and increased use of weight-reducing materials may also help to increase fuel efficiency by up to 15 percent. As in the case of motor gasoline, robust economic growth and low projected jet fuel prices are expected to result in strong growth in air travel (an estimated 3.6 percent per year between 1999 and 2020) and a corresponding 2.6-percent average annual gain in jet fuel consumption.

The United States has taken steps to limit exhaust emissions from its motor vehicle fleet. The Clean Air Act Amendments of 1990 (CAAA90) set "Tier 1" exhaust emission standards for carbon monoxide, hydrocarbons, nitrous oxides, and particulate matter for light-duty vehicles and trucks beginning with model year 1994. CAAA90 also required the U.S. Environmental Protection Agency (EPA) to study more extensive "Tier 2" standards that would be enforced on 2004 model year cars. In July 1998, the EPA provided Congress with a Tier 2 study which concluded that tighter vehicle standards are needed to attain National Ambient Air Quality Standards for ozone and particulate matter between 2007 and 2010.

In February 2000, the EPA published its Final Rule on "Tier 2" Motor Vehicle Emissions Standards and Gasoline Sulfur Control Requirements [***5***]. The Final Rule includes standards that will significantly reduce the sulfur content of gasoline throughout the United States to ensure the effectiveness of emissions control technologies that will be needed to meet the Tier 2 emissions targets in new automobiles and light-duty trucks, minivans, and sport utility vehicles (SUVs). The new standards represent the first time that the same set of emissions standards will be applied to all passenger vehicles, and the EPA has stated that the single standard is appropriate given the increased use of light trucks for personal transportation. The reference case projections for the U.S. transportation sector incorporate the new Tier 2 standards and low-sulfur gasoline requirements.

On December 21, 2000, the EPA also finalized new regulations to reduce emissions from heavy-duty trucks and buses substantially [***6***]. The sulfur content of highway diesel fuel is to be reduced from its current level of 500 parts per million (ppm) to 15 ppm beginning in June 2006. Refiners and importers will be required to produce diesel meeting a 15 ppm maximum requirement by June 1, 2006. Diesel meeting the new specification will be required at terminals by July 15, 2006, and at retail stations and wholesale outlets by September 1, 2006. This time schedule is driven by the need to provide fuel for the 2007 model year diesel vehicles that will become available in September 2006. New standards for heavy-duty gasoline engines and vehicles will reduce both hydrocarbons and nitrous oxide for all vehicles over 8,500 pounds not covered in the Tier 2 standards, beginning in 2005.

Under a "temporary compliance option" (phase-in), a refinery may produce up to 20 percent of its total annual highway diesel fuel at the current 500 ppm on-highway level. The remaining 80 percent must meet the new 15 ppm maximum. The rule provides for an averaging, banking and trading (ABT) program. Refineries that

[24]For example, the Energy Policy Act of 1992 sets new vehicle purchase mandates for vehicle fleet owners, whereby 70 percent of all vehicles must be fueled by alternative fuels by 2006. Also, under the Low Emission Vehicle Program, 10 percent of all new vehicle sales in States that agree to participate will be zero-emission vehicles by 2003.

produce more than 80 percent of their highway diesel to meet the 15 ppm limit can receive credits that may be traded with other refineries within the same PADD that do not meet the 80 percent production requirement. Starting on June 1, 2005, refineries can accrue credits for producing any volume of highway diesel that meets the 15 ppm limit.[25] The trading program will end on May 31, 2010, after which all refineries must produce 100 percent of their highway diesel at 15 ppm. The ABT program will not include refineries in States that have State-approved diesel fuel programs, such as California, Hawaii, and Alaska. There are also various provisions for small refiners[26] and for refiners in the so-called "Geographical Phase-In Area" (GPA).[27]

Canada

The transportation sector in Canada is similar to that in the United States. Like the United States, Canada is a geographically large country, and its population density is much lower than in many Western European countries or Japan. The Canadian consumer can be expected to drive almost as much as the American consumer, although motorization rates are slightly lower in Canada than in the United States (607 motor vehicles per thousand persons in Canada compared with 777 in the United States in 1999). Canada's vehicle fleet closely resembles that of the United States, in part because the North American Free Trade Agreement has served to unify the North American vehicle market [***7***].

Petroleum use dominates transportation in Canada, accounting for 90 percent of total energy use in the transportation sector. On-road vehicles use 74 percent of the oil consumed for transportation, and the remainder is used for air, rail, maritime, and agricultural purposes [***8***]. Transportation sector uses are also expected to account for more than 97 percent of the increment in Canada's oil use over the forecast period.

The Canadian government has instituted a voluntary average fleet efficiency program for new cars and light trucks that is similar to the programs established in the United States. Cars and light trucks have achieved the voluntary efficiency standards, but light-duty vehicle (LDV) efficiency improvements have slowed in recent years because of the increase in light trucks (including vans and sport utility vehicles) in the personal motor vehicle population [***9***]. Efficiency improvements have also slowed because turnover in the total vehicle stock has narrowed the gap between the efficiencies of the total stock and new vehicles. Future gains in efficiencies will be difficult because of the popularity of sport utility vehicles and vans. As in the United States, high per capita economic growth in Canada is expected to lead to higher consumer demand for larger, more powerful vehicles, which may offset the effects of technological advances that might improve efficiency.

The air infrastructure is well established in Canada with 26 airports that each handle more than 200,000 passengers annually. More than 26.7 million passengers passed through the country's largest airport, Lester B. Pearson International Airport in Toronto, in 1998 [***10***]. High economic growth is expected to increase the number of people traveling by air as higher personal wealth allows people to use air travel for vacations as well as business travel. The Greater Toronto Airports Authority expects the number of passengers passing through Lester B. Pearson to escalate in the next two decades and has begun work on a 10-year $2.9 billion renovation and expansion project for the airport that will include two new runways and the replacement of the two existing terminals with a single terminal capable of handling 50 million passengers. The airport expansion should be completed by the end of 2005.

Mexico

Per capita vehicle ownership is lower in Mexico than in the other countries of North America, estimated at 158 cars per thousand persons in 1999. Despite a lower motorization level, however, motor vehicle transportation has contributed to making Mexico City one of the most polluted cities in the world. When the city's smog reaches dangerous proportions, the center of the city is closed to traffic and production is shut down in several of the city's factories.

In an attempt to reduce air pollution caused by Mexico City's 2.5 million vehicles, the government has instituted a policy to restrict car use, the Un Día Sin Auto (One Day Without a Car) law. Cars with license plate numbers ending in 0 or 1 cannot be driven on Mondays, those ending in 2 or 3 cannot be driven on Tuesdays, and so forth, with no restrictions on weekends [***11***]. The success of the policy is questionable, however. While it appears to offer some measure of pollution relief by removing a certain percentage of cars from Mexico City's streets each day, some argue that people have simply found ways to get around the restrictions by either purchasing additional cars or adjusting their scheduled driving to meet the requirements, without actually reducing total driving time.

Mexico has invested at least $5 billion over the past decade in an effort to clean the air in Mexico City [***12***]. Outdated diesel buses have been replaced, a city oil

[25] Credits for 15 ppm diesel fuel can be accrued prior to this date if the refiner can certify that the fuel is to be used in vehicles certified to meet the heavy-duty engine standards for model year 2007.

[26] Small refiners are defined as those with fewer than 1,500 employees and corporate capacity of less then 155,000 barrels per day.

[27] Including, Colorado, Idaho, Montana, New Mexico, North Dakota, Utah, Wyoming, and parts of Alaska

refinery has been closed, and some of the hills near the city have been reforested, but ozone levels remain high. In September 1999, two transportation agencies in Mexico, Coordinacion De Transporte De Mexico, A.C., and “Ruta 89" Union De Taxistas Camesinos Libres Independientes, A.C., contracted with IMPCO Technologies to convert 4,100 public transportation vehicles in Mexico City to liquid propane gas systems from gasoline systems [***13***]. There are plans to convert 70,000 commercial vehicles in the city to liquid propane.

Mexico began producing cars with emissions controls in 1991 to mitigate growing concerns about air pollution [***14***]. The government has also established strict legislation on emission controls in taxis, trucks, minibuses, and private cars, and the state-owned oil company, Pemex, has been reducing production of leaded gasoline. In 1997, Pemex increased sales of unleaded gasoline; replaced Nova gas—which was a poor quality and highly polluting gasoline—with a higher octane gasoline; and replaced the high-sulfur diesel that was produced at the refineries with the new Pemex Diesel, which contains about 0.05 percent sulfur. These measures are expected to help limit growth in air pollution somewhat, but increasing levels of car ownership and rising highway use for trading purposes with Central America and the United States will mean that pollution will remain a problem for the country’s urban areas.

Western Europe

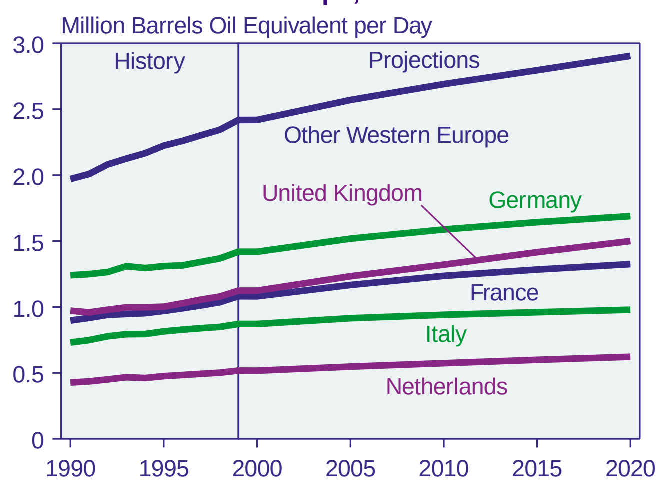
Western Europe’s transportation sector was the subject of much discord at the end of 2000. High world oil prices had a profound effect in the region, where high motor fuel costs were previously thought to be impervious to the volatility of world oil markets. In the third quarter of 2000, world oil prices edged passed $37 per gallon to the 10-year high level hit during the 1990-1991 Persian Gulf War, and European consumers (primarily truck drivers, taxi drivers, farmers, and fishermen) staged widespread strikes protesting the high fuel costs and demanding that governments lower federal gasoline taxes. The protests have ceased as oil prices have moderated.

Few European governments are expected to reduce motor fuel taxation levels. Taxes have been put in place to increase national revenues and to help keep consumer demand lower, and when oil prices begin to moderate gasoline and diesel prices are expected once again to fall into ranges that consumers can tolerate. Many European countries have urban mass transit systems that allow consumers to reduce driving commutes, unlike much of the United States. In the *IEO2001* reference case, demand for transportation fuels is expected to grow slowly in most Western European nations, averaging between 0.6 percent (Italy) and 1.5 percent (United Kingdom) annual growth from 1999 to 2020 (Figure 89).

One short-term effect of high gasoline prices in the United Kingdom has been a move toward smaller, more efficient motor vehicles. The United Kingdom has the heaviest federal tax burden on motor gasoline among Western European countries, at about 75 percent of the total cost of the fuel, including value-added tax and duties. The Royal Commission on Environmental Pollution has released a study showing that carbon dioxide emissions from new cars fell for the third year in a row in 1999, by 2.2 percent [***15***]. Further, compact car sales in the United Kingdom increased by 20 percent in the first half of 2000 alone, and mid-size and luxury car sales declined by 23 percent. This is in contrast to the United States where there has been little change in the relatively strong demand for sport utility vehicles. Instead, U.S. consumers have switched from premium to regular gasoline in the high oil price environment. As prices in the United States rose in 2000, the combined sales of mid-grade and premium gas fell by 21 percent in the first 9 months of the year, whereas sales of regular gasoline—typically about 10 percent cheaper—grew by 5 percent, accounting for more than 3 of every 4 gallons sold by the end of 2000 [***16***].

The strikes in Great Britain were especially dramatic, with freight trucks and taxi cabs blockading oil refineries throughout the country. More than 90 percent of the country’s 13,000 filling stations were reporting shortages or ran out of fuel altogether as panic buying spread and refinery tanker drivers were unable or unwilling to risk attempts to deliver new supply in the atmosphere of the week-long strike. Although officials in the Blair administration refused to reduce petrol taxes, they did concede at the end of the first week that they were

Figure 89. Transportation Energy Consumption in Western Europe, 1990-2020



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

willing to look at reducing (or at least not raising) motor fuel taxes in the next budget talks.

There are other indications that European consumers are becoming dissatisfied with the costs of owning and maintaining motor vehicles in today's high oil price environment. London's *Electronic Telegraph* reported that the costs of running a car in the United Kingdom increased by 60 percent over the past 10 years—strongly outpacing inflation [***17***]. The cost of unleaded gasoline increased from 42.8 pence per liter (about $2.38 per gallon) to 84.9 pence per liter ($4.73 per gallon) between 1990 and 2000, and the cost of diesel fuel similarly rose from 37.8 to 83.2 pence per liter ($2.11 to $4.61 per gallon). In 2000, the Royal Automobile Club (RAC) called on the British government to cut the costs of gasoline, and several freight and motorist associations, such as the Association of British Drivers and the Road Haulage Association, supported a "Boycott the Pumps" day to protest the high prices of transportation fuels [***18***] before the trucker strikes began in mid-September. The protest began on August 1 and was slated to continue on every Monday thereafter in an attempt to force the government to either lower the fuel tax burden on consumers or to at least guarantee that the taxes would be used to improve the overburdened and aging transportation network.

Despite the new-found consumer dissatisfaction with high gasoline prices, oil demand in Western Europe has not been markedly affected. Demand did not slow in 2000 until the third quarter, mostly because of the buffer that high transportation fuel taxes provide consumers [***19***]. In addition, strong economic growth and rising employment levels in the late 1990s and into 2000 resulted in strong growth in new car registrations. In the first five months of 2000, new car registrations increased by 2.7 percent over the same period in 1999, and the level for May alone was 10.4 higher than in May 1999. Although higher employment levels in Western Europe may lead to more commuter vehicle travel, the effects should be less dramatic than in the United States, because of the mass transit infrastructure that has been established in many European cities.

In terms of fuel mix, European consumption of diesel fuel is projected to grow faster than motor gasoline use (unlike the mix in Canada and the United States). Diesel fuel is currently taxed less than motor gasoline, although the disparities between the two sources are lessening in most countries. Also, diesel fuel has more energy content than gasoline, which means that drivers may buy fuel for their diesel vehicles less often than drivers of gasoline-fueled cars. The *IEO2001* reference case projects that diesel consumption will overtake motor gasoline consumption in Western Europe by 2020.

Industrialized Asia

The transportation sector of industrialized Asia (Japan, Australia, and New Zealand) is well established, and motorization levels are similar to those in other industrialized countries. The characteristics of the transportation infrastructure vary among the three countries, reflecting differences in population density and geography. Japan, which is more densely populated than Australia or New Zealand, has established extensive mass transit systems to accommodate commuters. Japan, roughly the size of California, has about 14,676 miles of railways, whereas Australia, only slightly smaller than the United States, has only about 24,840 miles of railways.

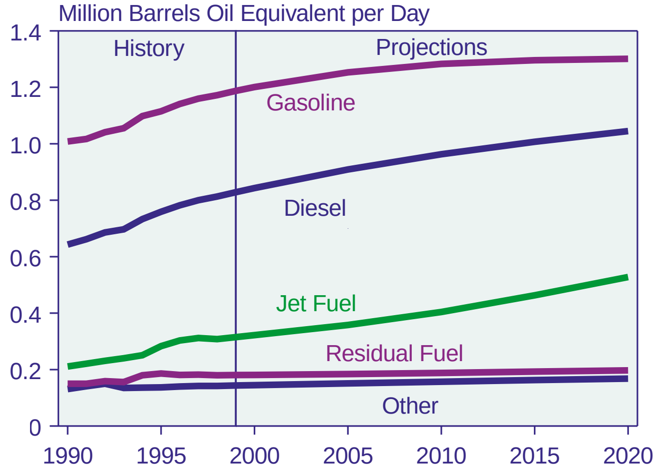
In Australia, the highest energy-consuming sector in the country is transportation, which currently accounts for 42 percent of total final energy consumption, compared with 35 percent for the industrial sector and 23 percent for the buildings sector [***20***]. Along with the nearly 25,000 miles of railways, Australia boasts some 503,010 miles of roads [***21***]. The country's current vehicle stock is estimated at 9 million, or about 637 vehicles per thousand persons.

Japan has a somewhat lower motorization level than does Australia, mainly because Japan relies more heavily on mass transit systems. Nevertheless, the share of energy consumption for transportation has been increasing in Japan, mainly due to rising demand for personal motor vehicles. Motor vehicle ownership rates in Japan grew by more than 50 percent between 1984 and 1998, and by 2020 they are expected to increase by another 13 percent as motorization reaches saturation levels. Most vehicles added at the end of the forecast are expected to be second or third family cars.

Japan's gasoline consumption currently represents 30 percent of the total Asian market (both developing and industrial Asia combined). Cambridge Energy Research Associates estimates that motor gasoline consumption in Japan grew by 2.0 percent in 2000, with very little impact from the increase in crude oil prices [***22***]. The average price for gasoline in Japan in the first half of 2000 was only 9 percent higher than in the first half of 1999, due to a combination of high gasoline taxes and vigorous competition among the liberalized Japanese retailers.

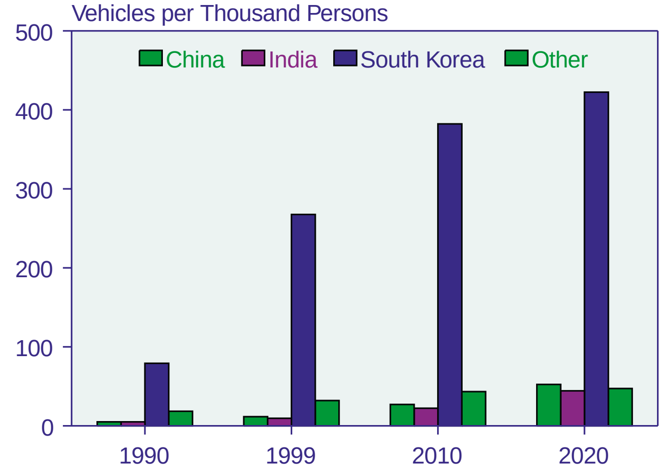
In all three countries of industrialized Asia, jet fuel consumption is expected to grow more rapidly than other transportation fuel use over the 21-year forecast period, by 2.5 percent per year, as compared with 0.4-percent annual growth projected for motor gasoline consumption and 1.1-percent growth for diesel consumption year (Figure 90). The importance of tourism to the economies

Figure 90. Transportation Energy Consumption in Industrialized Asia by Fuel, 1990-2020



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

Figure 91. Motorization Levels in Developing Asia, 1990, 1999, 2010, and 2020



Sources: **1990:** American Automobile Manufacturers Association, *World Motor Vehicle Data* (Detroit, MI, 1997). **1999, 2010, and 2020:** EIA, World Energy Projection System (2001).

of both Australia and New Zealand is reflected in the expectations for growth in jet fuel use. Of the 44 airports operating in New Zealand today, 8 are international airports (Auckland, Wellington, Hamilton, Palmerston North, Christchurch, Dunedin, and Queenstown) [***23***]. Australia currently has 8 international airports as well, and the largest, in Sydney, handles almost 21 million passengers each year. The total for domestic air services at all of Australia's airports is only about 18 million passengers each year [***24***].

Developing Asia

The transportation sector in developing Asia is a key indicator for the status of the region's economies. Motorization grew by double-digit percentages in the early and mid-1990s in many countries of developing Asia, as increasing prosperity resulted in more personal transport. The 1997-1999 economic recession in southeast Asia damped the trend, but in 2000 Malaysia posted a 22-percent increase in car sales and almost a 78-percent increase in car sales in Singapore [***25***]. In Thailand, sales of new cars jumped by 55 percent in 2000, as low interest rates sparked increased domestic demand [***26***].

China

In China, per capita motor vehicle ownership remains low and, despite the robust average annual growth projected for automobile sales, motorization levels are projected to remain low relative to the industrialized world throughout the forecast. At present, most of the motor vehicles in China are owned by government or corporations, not by individuals. While personal motor vehicle ownership is projected to increase in the coming decades and per capita motorization to grow to more than four times the 1999 level, the projection for 2020 is only 52 vehicles per thousand persons by 2020—about one-fifteenth the 1999 U.S. level and only one-fifth the 1999 level in neighboring South Korea (Figure 91). Passenger cars are expected to be the fastest-growing mode of transportation in China, but mass transportation systems are expected to remain the most widely used form of motorized transport in the country throughout the projection period.

High world oil prices have also affected China's gasoline prices. Between May and June 2000 retail gasoline prices in Beijing rose by 9 percent [***27***]. The government is trying to bring gasoline prices more in line with the world crude oil market by allowing domestic gasoline prices to change on a monthly basis, and the result has been a fast-paced increase in gasoline prices. Angry taxi drivers in Beijing staged a one-day strike in early July 2000 to protest rising gasoline prices.

India

Like China, India has not invested extensively in its transportation infrastructure, and its future economic expansion may be slowed as a result. India does not have a well-established interconnected transportation network. Rail accounts for the greatest share of interstate transportation. Although the country has an estimated 500,000 miles of paved roads, 38,000 miles of railways, and 11,000 miles of navigable channels, the roads and rail lines have not been maintained [***28***]. The railroad equipment is often outdated, and the poor condition of the roadways makes interstate motor travel difficult. Further, urban congestion is growing worse, causing air pollution problems in the major cities of India, along with a general difficulty in moving through the areas. India's airline infrastructure is similarly challenged because there has been little investment to improve airports or runways over the past several years.

Other Developing Asia

The main fear for the economies in other developing Asia is the potential impact of sustained high world oil prices on economies that have been in recovery since the southeast Asian recession. Malaysia and Indonesia have benefited from the high price environment because both are oil exporters, but both have also found it necessary to increase gasoline prices. In Indonesia—the last southeast Asian economy to show some recovery from the 1997-1999 recession—efforts to raise gasoline prices to reflect higher world oil prices were met by demonstrations from consumers after the first day of the rate increases.

The fast-paced growth in Malaysian car sales reflects a corresponding aggressive move by the government to enhance the transportation infrastructure of the country. The country's Seventh Malaysia Plan (1996-2000) made a priority of the development of roads, railways, ports, and airports [***29***]. Between 1995 and 1998, Malaysia's national road network grew by 6.1 percent, and privatized highways grew by 30 percent. Road construction has been particularly important to the Malaysian government in an effort to establish a link between the northern and southern parts of the country.

Malaysia has also established a major light rail transit (LRT) system and converted peninsular Malaysia's existing rail network from single to double tracks. LRT System I in Kuala Lumpur began operating in December 1996, and by the end of 1998 it was reportedly seeing 49,000 passengers each day [***30***]. A second LRT system came into operation in September 1998. Airports and ports have also been expanding because of a large influx of tourists and rising exports. In 1997, Malaysia reported that it had handled 30 million air passengers for the first time. In 1991, citing increased demand for air facilities to accommodate increasing tourism and commerce, the government decided to construct a new international airport facility. In September 1998, the Kuala Lumpur International Airport at Sepang was completed, with the ability to handle 65 to 67 planes per hour [***31***]. At present the airport is able to manage 25 million passengers each year.

Pakistan is working toward expanding its transportation infrastructure. The country has focused most of its effort on developing highways, which have doubled since 1980. Currently Pakistan has over 50,000 miles of paved roads and 8,000 miles of railways. Freight and passenger transport has been trending away from rail and toward road travel, and the result is that very little effort has been made to upgrade or expand the country's rail system. The country's main international airport, Karachi International, handles around 5 million passengers each year. Construction is underway on the expansion of Pakistan's Lahore International Airport. Lahore currently serves more than 2.5 million passengers each year, but the government expects the number to grow to 6.5 million by 2015 [***32***].

Many countries of developing Asia are experiencing growing pains. Strong economic growth has increased the demand for personal motor vehicles, and transportation infrastructure has not always been able to keep pace with the growing demand. In the Philippines, for example, road transport accounts for nearly 80 percent of total transportation energy consumption, and new automobile sales—notwithstanding the sharp decline during the height of the Asian economic crisis—have increased at a steady rate [***33***]. Standard & Poor's estimates that current motorization in the Philippines is about 30 vehicles per thousand persons and expects that level to triple over the next two decades. The transportation sector currently accounts for only 20 percent of total energy consumption in the Philippines, and poor road upkeep and lack of expansion have kept the sector from growing more rapidly.

South Korea enjoyed exceptional growth in the number of passenger cars per person during the 1980s and through the 1990s, and the country is expected to continue the expansion of motorization, reaching saturation before the end of the forecast period. Motorization grew by 16.9 percent per year in South Korea between 1980 and 1999; but the growth rate is expected to slow considerably over the projection horizon to 2.2 percent per year between 1999 and 2020.

With the major increase in the number of motor vehicles on the roadway (the automobile fleet increased from 5.2 million vehicles in 1992 to an estimated 10.5 million in 1998 [***34***]), congestion and urban air pollution have become a major focus for the South Korean government. The Korean Ministry of Construction and Transportation Plans to introduce electric railways in major urban areas to alleviate the problem. There are additional, long-term plans to connect major cities with an electricity-fueled network of railways [***35***].

Another Asian country that is projected to reach motorization saturation levels over the forecast horizon is Taiwan. The country has already achieved car ownership levels estimated at 245 per thousand persons, similar to the levels of South Korea [***36***]. The Taiwanese government is concerned about the need to enhance the country's transportation infrastructure and, particularly, the need for mass transit options to counteract the potential for traffic congestion that will undoubtably occur over the forecast period. In Taipei, a rapid transit line was first opened in 1996, the so-called "Mucha Line" with 12 stations and 6.5 miles of elevated track [***37***]. Since then the line has expanded by more than 20 miles and there are plans to add another 23 miles by 2005. The government has also been improving the road connections between islands and improving roads to major production centers [***38***].

After contracting by 10.2 percent in 1998, Thailand's economy substantially recovered with 4.2-percent economic growth in 1999 and an estimated 4.2 percent in 2000 [***39***]. Sales of motor vehicles in Thailand plummeted by nearly 60 percent in 1998, after a 38-percent drop in 1997 [***40***], but in 2000 the motor vehicle markets appeared to have regained the momentum lost during the southeast Asian recession. By the second quarter of the year, car sales were up by more than 50 percent and motorcycles more than 67 percent over 1999. Some analysts have noted, however, that consumer worries about persistent high oil prices might jeopardize the recovery of the Thai automotive industry [***41***].

The boom in personal motor vehicle ownership in Thailand began in the early 1980s when the government lowered import duties on automobiles. Unfortunately, efforts to improve and expand the transportation infrastructure have not, by and large, kept up with the fast-paced growth in motorization. Bangkok, the country's largest city, is notorious for its traffic jams and air pollution. To address the issue of commuter congestion, Thailand constructed an elevated electric rail system, called Skytrain, which went into operation at the end of 1999. The 14.6-mile rail consists of two routes: the Sukhumvit Route (from On Nut Intersection to Banthad Thong Road) and the Silom Route (from Mor Chit to Silom and Taksin Bridge). The country has plans for construction of another 160 miles of mass transit systems (trains and subways) over the next 5 to 6 years [***42***].

Middle East

In the Middle East, transportation infrastructure has not been extensively developed. Motorization levels are relatively low and are expected to grow slowly, in part because many Middle Eastern countries actively discourage women from driving, ultimately limiting the population able to own automobiles [***43***]. Nevertheless, in the *IEO2001* reference case motorization rates are projected to increase by 3.8 percent per year, to 124 vehicles per thousand persons by 2020—still substantially lower than today's motorization rates in the industrialized world.

Since the end of the Iran-Iraq War in 1988, Iran has experienced substantial growth in its transportation sector energy use. Transport energy consumption has increased by about 6 percent per year as reconstruction of the oil refinery network has allowed the easing and eventually the removal of fuel rationing [***44***]. To accommodate growing demand in the transportation sector, the government is making the improvement of the transportation network one of the priorities of Iran's Third Five-Year Plan, which runs from March 2000 to March 2005 [***45***]. Between 1999 and 2000, the government spent more than 60 billion rial (about $34 million) to construct roads in Zahedar province alone.

There are also several highway construction projects underway within Iran. The government is attempting to improve the interconnections between cities. In 1999, the 62-mile Amir Kabir freeway was completed, connecting Qom Province to the city of Kashan in Isfahan Province. Amir Kabir was constructed to improve the connection between cities and ports in the southern and central parts of the country, allowing freight traffic to move more easily [***46***]. In August 2000, the Irani government announced plans to construct the 76-mile Tehran-Shomal highway in northern Iran to connect Tehran with northern Iranian cities Chaloos, Noshahr, and Clardasht [***47***]. The project, which is to be constructed through dense forest land, may take as long as seven years to complete and would require the excavation of an estimated 1.8 billion cubic feet of soil.

As in many other urban areas of the developing world, the expansion of the transportation sector has brought increasing concerns over air pollution in Iran. In June 2000, the country's Department of Environment recommended that Tehran Mehrabad International Airport be relocated from its present site because it is aggravating the air pollution problem in Tehran [***48***]. The Department of Environment estimates that the airport is responsible for 15 percent of the total air pollution in Tehran. Several mass transit rail projects have also been considered, in part, to address environmental concerns. In early 1999, the Tehran-Qom express railway became operational. The 85-mile railway is expected to transport 5.5 million passengers and 8 million tons of cargo each year [***49***].

Another Middle Eastern country that has seen fast-paced growth in its transportation sector is Israel. The number of cars in Israel has increased rapidly since 1985, a result of increasing economic prosperity, and motor gasoline use has grown by an estimated 5 percent per year during the period [***50***]. The Israeli government estimates that over the next decade motorization levels will grow by 6 to 7 percent per year, and that the country's automobile fleet will grow from present levels of 1.4 million vehicles to 2.0 million [***51***]. One way in which the government plans to prepare for the growing traffic involves the construction of the 186-mile Cross Israeli Highway, which will span from the Galilee region to the Beer Sheba area. The first phase of the highway is expected to run parallel to the Tel Aviv metropolitan area and will be about 60 miles long. It is scheduled for completion by 2002.

Israel's Ben Gurion International Airport serves about 7.4 million passengers each year [*52*]. Increasing tourism and business travel are expected to drive growth in air travel in Israel, and the government has estimated that the airport will have to be able to handle as many as 16 million international travelers a year by 2010 [*53*]. With that in mind, the Israeli Transport Ministry has invested some $500 million in improving the infrastructure of the Ben Gurion Airport and expects to invest an additional $330 million in improvements before 2010.

Several road and airport projects are planned for the transportation sector development in the United Arab Emirates (UAE) [*54*]. The Ministry of Public Works and Housing started construction on 15 highway projects in 1997, as well as several maintenance projects. The country also has plans to construct a major inter-Emirate highway that would, at completion in 2005, link all seven emirates, from Abu Dhabi to Ras al-Khaimah and across to Fujairah. There are government plans to upgrade and expand the UAE's six international airports. By 2002, Abu Dhabi International Airport plans an additional runway and satellite terminal, and Dubai International Airport is also currently being expanded.

There are several plans for improving international road construction in the Middle East, including roads connecting Egypt, Israel, Jordan, and the Palestinian Authority; Haifa-Jordan highway; Amman-Jerusalem-Ashdod highway; and a future central corridor network that would link Syria, Lebanon, Jordan, Israel, Egypt, and the Palestinian Authority. No plans have been solidified yet, however, and in the current political atmosphere it is unlikely that anything will go beyond the planning stages for the time being.

Africa

Africa's transportation sector has not expanded to the extent that it has in other developing regions, and the limited number of existing roadways have not generally been maintained. Low per capita incomes have kept the number of vehicles per person among the lowest in the world [*55*]. For example, in Nigeria—Africa's most populous country—there are only an average 12 vehicles per thousand persons, and even in South Africa—the region's most developed economy—there are only about 139 vehicles per thousand persons [*56*]. In much of the region, railways are primarily used to transport goods to the marketplace, but locomotives are old and outdated, and railway lines are in disrepair.

Most African governments subsidize petroleum products to protect consumers from higher oil product prices. (One reason for the subsidies is to encourage the population to use oil products rather than wood fuel, in an effort to limit deforestation.) When Ghana and Nigeria attempted to raise the prices of gasoline in 2000, the local populations were quick to protest [*57*]. In the case of Nigeria, the Nigerian Labor Congress threatened a general strike that quickly resulted in the government's rescinding the price increase [*58*]. Because higher oil prices result in stronger inflation, low-income Africans cannot afford to spend more for energy and for other products. Also, higher end-use prices might further encourage illegal trade rather than fostering energy efficiency and reducing consumption.

Nigeria

In the 1970s, high world oil prices enabled oil-exporting Nigeria to construct an extensive transportation infrastructure to ease the shipping of the oil it produced to its marketing centers. The country currently has more than 20,000 miles of paved roads and about 2,000 miles of railways [*59*]. Unfortunately, political instability, government corruption, and low economic growth in recent years have made it difficult for the country to invest in repairs, and roads and rail lines have deteriorated over the past two decades.

Since 1999, when President Olusegun Obasanjo assumed office, the Nigerian government has announced plans for a number of road, rail, and airline infrastructure improvements. The country's Petroleum Trust Fund has pledged to invest nearly $1 billion in road network improvement [*60*]. Nigeria has also pledged to rehabilitate some 12,000 miles of surfaced road over the next 4 years [*61*]. The country is interested in co-financing development of a trans-Saharan roadway that would link Nigeria to its neighbors Algeria, Chad, Mali, and Tunisia, improving the ability to travel between the countries, as well as improving trade opportunities.

The World Bank is supporting efforts to establish a light rail project for Lagos, and the Nigerian government announced plans for eventually constructing 3,190 miles of rail to interconnect the country and take the pressure off shipping freight via roads alone [*62*]. The Nigerian government estimates that only about 0.05 percent of the country's freight is carried by rail. The Transport Ministry has made improving rail a priority, and the Nigerian Railways Corporation is scheduled to receive 55 percent of the total capital expenditure of the ministry in 2001, some $15 million, for this purpose [*63*].

Airlines in Nigeria have also fallen into disrepair, and airline travel has declined substantially over the past several years. This may, however, change with the privatization of the state-run airline, Nigeria Airlines Limited (NAL). The Nigerian government and the World Bank signed a pact to restructure NAL in October 1999 [*64*]. Further, the U.S. Export-Import Bank recently guaranteed $200 million in loans to assist Nigerian private airlines in upgrading their aviation equipment and aircraft [*65*].

South Africa

Another African country with a fairly extensive transportation network is South Africa, where there are good interconnections among the country's industrial production centers. However, the transportation infrastructure has not kept pace with its needs. South Africa has more than 35,000 miles of paved roads, including highways, and more than 13,000 miles of railways [***66***]. The government allocated about $472 million in fiscal year 1993 and $489 million in fiscal year 1994 for road maintenance and repair, with another $500 million in 1995. In 1999, South Africa's Department of Transport began a 2-year, 20-road project (including toll roads) at a cost of more than 5 billion rand (about $635 million). The Department of Transportation estimated in 1995 that 170 billion rand ($22 billion) will be needed for road infrastructure expansion and maintenance over the next several years [***67***].

There is a substantial railway network in South Africa, serving the mining and heavy industries of the country along with those of neighboring countries. Spoornet is the largest heavy hauler and transporter of general freight in South Africa [***68***]. It was created in 1990 when the South African government decided to commercialize its transportation sector business interests and deregulate the transportation industry in the country. The railway system seems to be suffering from the poor economic conditions of the past 2 years, however. Spoornet went from making a profit of $76 million in 1998 to losses of $17 million in 1999 and $25 million in 2000.

The airline infrastructure of South Africa needs substantial improvement to be able to accommodate expected growth in tourism and business travel over the next decade. Already, the country's main international airport, Johannesburg International (formerly Jan Smuts International), handles around 5 million passengers each year, and the South African government estimates that the number of passengers traveling through the airport could reach 40 million by 2030 [***69***]. As a result, Airports Company South Africa (ACSA), the country's main airline services company, expects to invest some $150 million in major capital expenditures for expanding and improving the country's air infrastructure. Half the investment is designated for the Johannesburg International Airport. The ACSA operates nine of the country's major airports—Johannesburg International, Capetown International, Duban International, Kimberley Airport, Port Elizabeth Airport Bloemfontein Airport, George Airport, East London Airport, and Upington Airport—and in 1999 acquired Pilanesberg International Airport near Sun City.

Morocco

Morocco has a more extensive road network than do most of the other African countries. Morocco is a natural transit point between Europe and Africa, and there are plans to expand the transportation infrastructure in the near future [***70***]. In terms of the road network, the north-south axis of the country is well established, with more than 36,000 miles of roads [***71***]. Highways link Casablanca to Tangier (in the north) and to Agadir (in the south). The country is currently developing its east-west axis. The Moroccan government has committed to connecting all the country's major cities with paved roads by 2002 [***72***].

Rail transportation under the control of the National Office of Railways, is also relatively well established in Morocco, with about 1,200 miles of rail lines [***73***]. A rapid commuter service is in operation linking Rabat, Casablanca, El Jadida, Marrakesh, and Agadir. Tourism is a growing part of the Moroccan economy, and air travel is of growing importance. The country currently has 11 international airports operating, and European tourists are also able to travel to the country easily via ferry.

Algeria

Algeria has more than 64,000 miles of roads and around 3,000 miles of railways [***74***]. Most goods in the country are transported by rail, and modernization of the country's railways is considered a priority. In October 1999, Algeria reached a $2 billion agreement with French companies Spie Enertrance, RailTech, and Cogifer Travaux Ferroviaires on a 10-year contract for maintenance of existing rail lines and system expansion. The state-owned Societe Nationale du Transport Ferovier owns 200 trains that were acquired by Algeria in the 1970s and should be upgraded or replaced.

The Algerian road network is fairly extensive, although much of it has been established to support the shipment of oil, which is a major export of the country. The first phase of the trans-Saharan highway, linking Algiers to Lagos, was completed in 1985, and the project has now been extended. It will connect Algeria to Chad, Mali, and Tunisia when completed [***75***]. The European Investment Bank has approved a 45 million euro loan (about $48 million) to Algeria to finance the construction of a 50-mile section of highway to help integrate the road network of Algeria with Morocco and Tunisia [***76***].

Central and South America

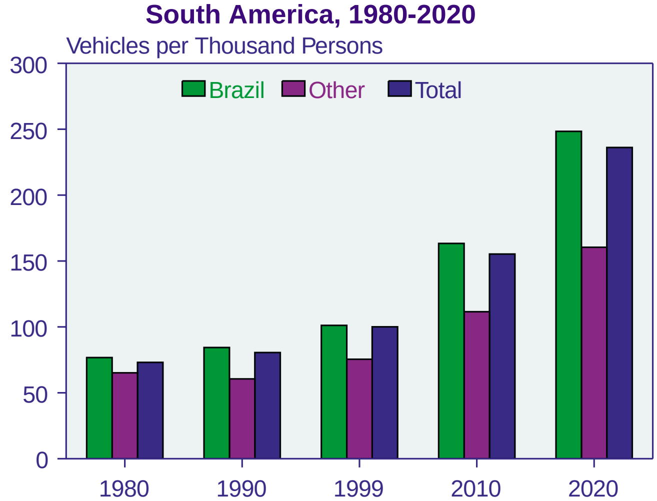
The transportation sector in Central and South America is projected to be one of the fastest-growing worldwide. While car sales fell during the recession that hit the region after the 1999 devaluation of the Brazilian real and the spillover impact from the Asian economic crisis, in 2000 new car sales began to recover. The *IEO2001* reference case expects transportation energy use to increase at an average annual rate of 4.6 percent between 1999 and 2020. Motorization rates are projected to expand by 4.2 percent per year, from 100 vehicles per thousand persons in 1999 to 236 in 2020 (Figure 92).

Brazil

Brazil, the region's largest economy, in 2000 showed clear signs of full economic recovery from the 1999 devaluation of the real and subsequent recession. The Brazilian economy grew by 0.8 percent in 1999 and by an estimated 4.2 percent in 2000 [***77***]. Automobile production, in particular, has made a strong recovery since 1999, increasing in August 2000 by nearly 27 percent compared to August 1999, and in July 2000 by nearly 23 percent compared to July 1999. Automobile exports and domestic sales have both been strong throughout the past year. High world oil prices have not yet had an impact on consumers in Brazil. The government sets fuel prices, and in September it announced that there would be no increases in prices for the rest of 2000.

Brazil has approximately 115,000 miles of paved roads, including 3,109 miles of the Trans-Amazonian Highway, which runs from northeastern Brazil to the Peruvian border and connects with the road networks of Colombia and Peru [***78***,***79***]. Expansion of the road infrastructure remained a priority in Brazil even during a slowdown in construction due to the brief 1999 recession [***80***]. The improvements to the country's road network have accompanied rapid expansion of personal motor vehicle ownership. Between 1994 and 1998, automobile sales in Brazil averaged 12.5 percent per year and, although they dropped in 1999, by mid-2000 they were averaging about 20 percent higher than in 1999 [***81***].

Figure 92. Motorization Levels in Central and South America, 1980-2020



Sources: **1980 and 1990:** American Automobile Manufacturers Association, *World Motor Vehicle Data* (Detroit, MI, 1997). **1999, 2010, and 2020:** EIA, World Energy Projection System (2001).

Brazil has a unique fuel mix in its automotive sector in that the country's vehicle fleet uses not only gasoline and diesel but also smaller amounts of alcohol and natural gas. Alcohol fuel use is a legacy from the 1979 Proácool program, in which the government encouraged the consumption of ethanol to ease Brazil's dependence on foreign oil, allowing the country to expand its oil production and reserves. The government is currently considering a proposal to reduce the amount of anhydrous alcohol to be mixed with gasoline to 22 percent from 24 percent, mostly because sugar cane productions has been reduced by a drought and there is concern that there may not be enough sugar cane to meet the internal demand for alcohol fuel [***82***].

There are about 17,000 miles of railways in Brazil, however, the trend for moving freight and passengers has been shifting toward road transport and away from rail, and the rail system is not receiving the same fiscal emphasis as the road infrastructure. The rail network has suffered from lack of investment and maintenance over the past several years [***83***].

Argentina

Most of the countries of Central and South America showed economic improvement during 2000, after the 1999 recession. Argentina, however, is among the few countries in the region where the recession lingered through 2000. After Argentina's economy shrank by 3.2 percent in 1999, it grew only by an estimated 1.5 percent in 2000 [***84***]. Political and social problems continued in Argentina, and the De La Rua administration has been unable to enact policies that would help to spur economic growth. Further, several political scandals (including a Senate bribery scandal that was followed by several high-profile suicides) and corruption charges have made the country unattractive to foreign investors.

Argentina has around 40,000 miles of paved roadways and 24,000 miles of railways. Motorization levels in the country are fairly high relative to much of the rest of the region, currently estimated at 179 vehicles per thousand people. The high economic growth enjoyed by Argentina for much of the 1990s resulted in increasing per capita incomes that have, in turn, resulted in strong growth in demand for personal motor vehicles. As a result, new automotive plants have been built in Argentina by the world's major car and truck manufacturers. In 1998, however, total car and truck production began to decrease and sales fell as the government and international creditors restricted access to credit, and demand from the rest of the Mercosur trading block[28] members slowed.

[28]The Mercosur trading block is made up of Argentina, Brazil, Paraguay, and Uruguay. Chile and Bolivia are Associate Members.

Argentina was particularly hard hit by the economic turndown in Brazil. Automobile exports to Brazil plummeted in 1999, and the domestic automotive market was severely weakened in 2000 when the government ended its "Plan Canje Plus," which subsidized consumer automobile purchases [***85***]. The economic troubles that began in 1999 caused a delay in finalizing the Mercosur automotive agreement on joint automobile regulations among Mercosur member countries (the "Politica Automotriz Mercosur"), but talks resumed in 2000 and the agreement was signed in Buenos Aires on March 23, 2000 [***86***]. The agreement includes a common external tariff of 35 percent on all vehicle imports into Mercosur nations [***87***]. Uruguay and Paraguay—which argued that the 35-percent tariff was unfair to them because neither country has a domestic automotive industry—agreed to a lower tariff of 23 percent, which will remain in force through 2005.

The restructuring of Argentina's air transport sector has slowed with the weak economy, political crises, and high unemployment. The De La Rua administration, which came to power in January 1999, suspended ratification of the air transport deregulation agreement that was signed by the previous administration until the problems with the country's major airline, Aerolíneas Argentinas, are resolved [***88***]. In 1990, Aerolíneas was one of the first Argentine public-sector companies to be privatized; however, its financial performance is among the worst [***89***]. The airline was sold to Iberia in 1990, clear of debt, but at the end of 1999 it was some $874 million in debt, and the Spanish holding company Sociedad Española de Participaciones Industriales (SEPI) had to come up with $208 million to keep it from declaring bankruptcy [***90***]. In October 2000, SEPI agreed to invest $650 million in Aerolíneas but stated that it plans to sell its interest in the airline once it has returned to financial health.

Other Central and South America

The development of the transportation sector in other Central and South American countries varies considerably as a result of differences in political and social issues, geography, and levels of investment. Colombia's main political challenge continues to be the resolution of armed conflicts between the government and the various guerilla entities operating in the country. As long as the government is unable to establish a lasting peace, it will be difficult to attract foreign investment. The United States has granted Colombia $1.3 billion in military aid over the next 2 years for the purpose of fighting drug trafficking, but because the drug cartels operating in the country have well-known ties to the guerillas, it appears that the money will, at least indirectly, be used against the guerillas [***91***]. Colombia's oil pipelines continue to be popular targets for terrorists, and acts of violence in oil-producing parts of the country make it less attractive to oil companies than other countries in Central and South America.

Colombia's political problems compound its problems in expanding and maintaining transportation infrastructure. Mountainous terrain has always impeded the development of the transportation network, and the threat of terrorist attacks on roads and (more often) pipeline projects has made it nearly impossible to establish the transportation network required to support increasing economic growth. The country does remain an important connection for transporting goods and people through the Andean region [***92***]. A portion of the Pan-American Highway runs through the country and links to roads serving important Pacific ports [***93***]. However, only a small portion of Colombia's roads are paved—approximately 12 percent of the total of 72,000 miles of highways. There are plans to improve the road linkages with ports, and the Colombian government plans to invest $141 million in the port system's land access infrastructure.

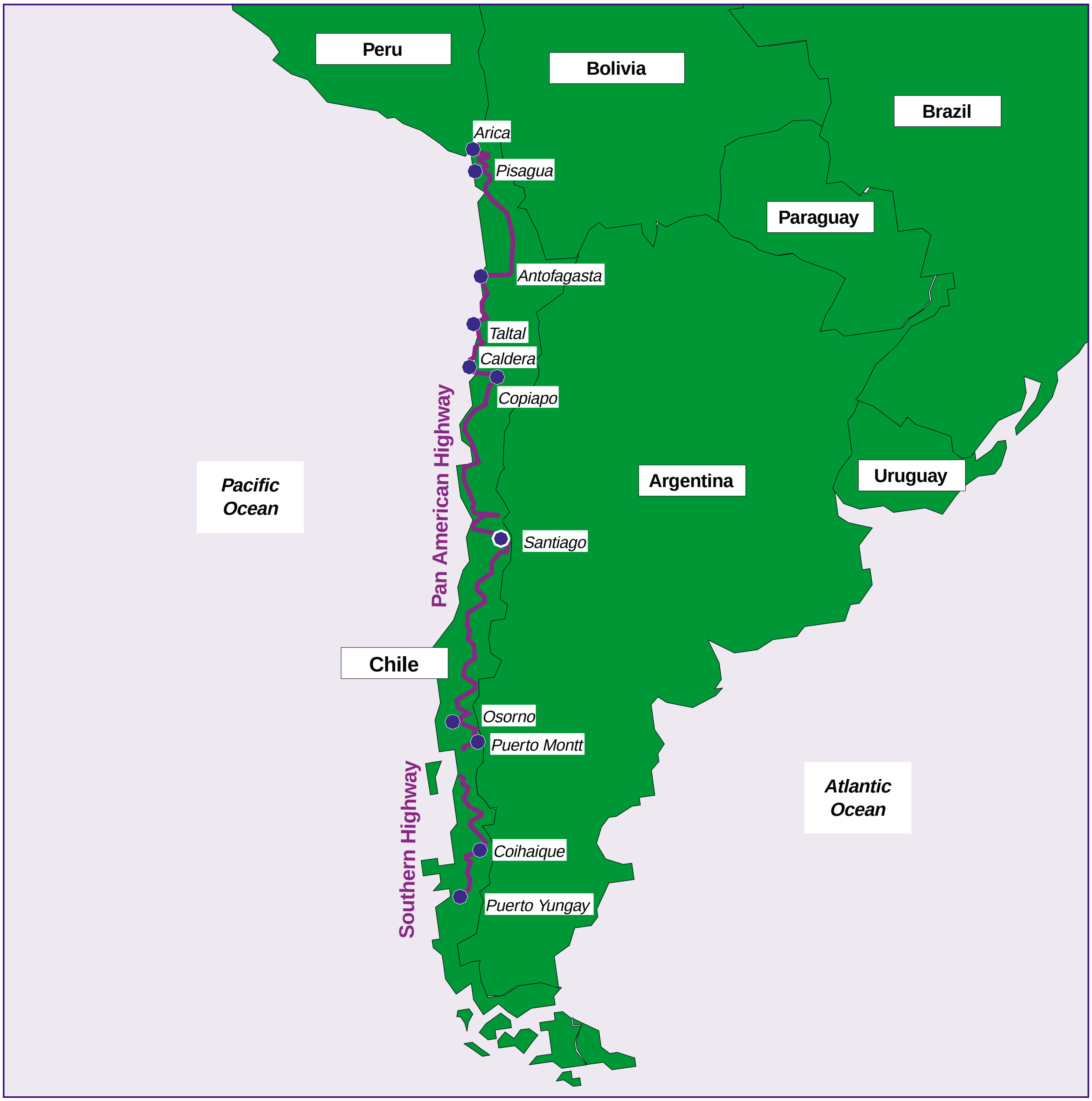
In Chile there are around 6,800 miles of paved roads, and the country is connected to neighboring Peru by 2,200 miles of the Pan-American Highway (Figure 93) [***94***]. Road transport is the primary mode by which people and freight are moved. As a result, the government has placed an emphasis on road maintenance and development in its plans for transportation network support, awarding more than $1 billion in road concessions to allow private firms to construct and manage toll roads and to maintain the Pan-American Highway (the country's primary north-south route). Currently, private companies are constructing 16 road and tunnel projects in which the property will be owned by the public sector but road tolls and maintenance fees will be paid to the companies.

Air transportation in Chile is well established, and the country's main international airport, Comordoro Arturo Merino Benítez (in Santiago) handles an average 2 million passengers per year and is served by 18 international airlines. The country has 390 airports, but only 48 have paved runways. Air traffic increased dramatically in the early 1990s, by 56 percent between 1990 and 1993 alone. Línea Aérea Nacional de Chile (LAN-Chile), the largest domestic carrier, was privatized in 1989 and currently handles 46 percent of the country's domestic passengers and 84 percent of its international passenger movement.

Peru has been plagued by political problems over the past few years, but they do not appear to be impacting the country's economy, which grew by 3.8 percent in 1999 and an estimated 4.9 percent in 2000 [***95***]. In 2000, the Fujimori administration announced that new elections would be held in April 2001. The announcement was made after the April 2000 presidential election, which was widely characterized by outside international observers as flawed. The move was precipitated by a video tape released to the press showing Fujimori's spy chief, Vladimio Montesinos, bribing an opposition congressman, Alberto Koury, in an effort to persuade Koury to change his party affiliation [***96***]. In July, after the Peruvian congress approved Fujimori for a third presidential term, new automobile sales fell by almost 20 percent from the previous year, and it now appears that political instability may be making consumers nervous.

Peru's transportation sector is among the smallest in South America. Mountainous regions, dense jungles, unpaved highways, and earthquakes have all worked to constrain development of the transportation sector. Although the government has eased import restrictions on both old and new cars, vehicle ownership remains low—40 vehicles per thousand persons, compared with the regional average of about 99 vehicles per thousand persons. The country is connected to Colombia and Chile by 1,550 miles of the Pan-American Highway

Figure 93. Major North-South Highways in Chile



Source: U.S. Department of Commerce, International Trade Administration, "Chile—Transportation Overview: Map of Chile's Transportation System," web site www.ita.doc.gov/td/transport/ci-oview.htm (not dated).

system, and it has approximately 4,740 miles of paved roads.

Venezuela has around 20,000 miles of paved highway and is interconnected to Guyana and to Colombia by 802 miles of the Pan-American Highway system [***97***]. It boasts the highest percentage of paved highways in the entire Central and South American region. As a major oil exporter, Venezuela used its profits in the 1970s to construct a relatively sophisticated transportation network. Most of the country's transport of goods and people are by roadway. Car ownership is estimated at 103 cars per thousand persons, higher than in neighboring Colombia and Guyana, and Venezuela is the third largest producer of cars in Latin America, after Brazil and Argentina. The government made road transportation its priority as early as the 1940s, when it began reducing investment in the Venezuelan railroads in favor of developing road infrastructure. There are only about 360 miles of rail operating in the country today, but in 1999 the government announced plans to upgrade and expand the rail system by increasing rail mileage to 2,500 miles by 2004, including construction of a link between Los Teques in Miranda State and Caracas.

Eastern Europe and the Former Soviet Union

The economic and political upheaval that took place in Eastern Europe and the former Soviet Union (EE/FSU) in the early 1990s has had a negative impact on the upkeep and development of the region's transportation infrastructure, particularly in the former Soviet republics, where economic growth has largely lagged behind that in the countries of Eastern Europe. Railways and public transportation have suffered from a lack of investment for maintenance and upgrade, and roads have also fallen into disrepair in many of the FSU countries. In addition, the lack of economic growth has meant a stagnation in the demand for new automobiles.

The *IEO2001* reference case forecast expects that economies both in Eastern Europe and among the former Soviet republics will recover over the next two decades, with a corresponding recovery in demand for transportation fuels and personal motor vehicles. Motorization levels are projected to grow from 158 vehicles per thousand persons in 1999 to 218 vehicles per thousand persons in 2020 in the EE/FSU, an expansion of about 1.5 percent per year. Fuel use in the transportation sector is projected to grow by an average 2.8 percent per year.

Russia

Russia, the largest economy in the EE/FSU region, relies on roads to move half its freight to market. The country has almost 590,000 miles of road, but only a little more than one-third are paved [***98***]. According to the U.S. Department of Commerce, Russia needs to add an estimated 900,000 miles of hard-surfaced roadways, and an estimated $3 billion will be needed to construct new roads and maintain the existing roadways [***99***]. The urgency of new road construction is apparent in Russia. Even in the wake of the August 1998 collapse of the ruble, road construction increased by 14 percent in 1998 and 3,300 miles of new road were built. However, the Russian Federal Road Fund, which had previously been used to pay for all road repair and development in Russia, faced major budget cuts after the 1998 monetary crisis, and as a result the government began to allow private toll roads to be constructed [***100***]. The World Bank has also begun to help the country finance road construction, allocating loans of $650 million for road construction projects between 1996 and 1998 and another $400 million at the end of 1998 for high-priority road network expansion in Siberia and Far East Russia, which should be completed by 2004 [***101***].

Russia's railroad infrastructure has also been neglected in the wake of the dissolution of the Soviet Union. In 1996, the European Bank for Reconstruction and Development (EBRD) approved a $120 million, 13-year loan to the Russian Ministry of Railways for "urgent improvements" to the country's rail network [***102***]. The funds were to be used to improve the tracks along high-density rail routes, particularly on the important routes of Moscow to St. Petersburg, Moscow to Nizhni Novgorod, and Moscow to Samara. In 2000, a second railway modernization loan was approved for $200 million to support further modernization of track and upgrades to freight and passenger cars and equipment [***103***]. Freight and passenger rail traffic have declined over the past several years as road transport has become a more important means of moving people and goods, and the Russian government hopes that the revitalization projects will strengthen the rail sector.

Although Russia has almost twice as many people as Germany, its new car sales in 1999 were only one-quarter of the number in Germany [***104***]. As the economy recovers over the projection period, personal motor vehicle demand is expected to increase, and the potential market is making Russia attractive to foreign car manufacturers. Currently Russia is the twelfth largest car producer in the world, and most of the demand for new automobiles is for domestic vehicles, such as the Lada and GAZ, which are much cheaper than western automobiles. Italy's Fiat, France's Renault, the Czech Republic's Skoda, and U.S. auto companies Ford and General Motors all have plans to invest in the automotive sector in Russia between 2001 and 2005.

Other Former Soviet Union Countries

Other FSU countries are also trying to improve their transportation infrastructures in efforts to improve networks for moving freight and people. The EBRD has several loan projects slated throughout the former

Soviet republics to improve the transportation sector, including: rehabilitation of a 440-mile highway in Ukraine (100.5 million euro—currently about $94 million); multiple road maintenance and improvement projects in Azerbaijan (about $99 million); and upgrade and modernization of 75 miles of railway track in Lithuania (about $89 million) [***105***]. Similarly, the World Bank is providing $40 million in loans to Georgia for road maintenance and to improve the country's main road network, as well as $29 million to Uzbekistan to upgrade urban transportation (providing new buses and repairing existing ones) in projects that should be completed by 2004 [***106***]. In 1999, the World Bank approved a loan of $100 million to Kazakhstan to rehabilitate priority sections of national roads and to fund the construction of new road and maintenance of other key roads [***107***].

Eastern Europe

With a greater pace of economic growth than in the FSU and greater proximity to Western Europe's markets, East European countries have generally fared better in terms of attracting foreign investment to build and maintain roads, as well as investment in their automotive sectors. Several car manufacturers have established automotive assembly plants, including Volkswagen, which invested in a plant at Bratislava, Slovakia, that in 2000 produced 200,000 cars for export to Western European markets [***108***]. Car exports have become a key element of the Slovakian economy, accounting for more than 20 percent of its total exports.

Other East European countries are also recognizing the importance of the transportation infrastructure in maintaining economic growth. Unless goods and people (tourism is becoming increasingly important to many East European countries) can be moved efficiently through a country and to the marketplace, economic improvement stagnates. Croatia is currently attempting to attract investment to improve its road infrastructure. The country has the potential to be a major thoroughfare linking Italy to Greece and Turkey by way of Slovenia, Croatia, Bosnia, Montenegro, and Albania [***109***], and a proposal for construction of an Adriatic-Ionian highway is currently being considered by U.S. company Bechtel. If approved, construction is slated to begin in 2003 and is estimated to cost between $5 and $12 billion.

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Environmental Issues and World Energy Use

In the coming decades, global environmental issues could significantly affect patterns of energy use around the world. Any future efforts to limit carbon emissions are likely to alter the composition of total energy-related carbon emissions by energy source.

This chapter examines the link between energy use and the environment worldwide, with particular emphasis on the *International Energy Outlook 2001* (*IEO2001*) projections for energy consumption and associated carbon dioxide emissions over the next 20 years. Regulations to reduce regional energy-related emissions of sulfur dioxide and nitrogen oxides, which are linked to several environmental problems, are also discussed (see box on page 170).

Global climate change is a wide-reaching environmental issue. The ongoing debate over climate change and how it should be addressed is a prime example of the divergence between concerns about energy supply and the environment. 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 land-use changes. Net carbon dioxide releases from these two sources are believed to be contributing to the rapid rise in atmospheric concentrations since pre-industrial times[***1***]. Because estimates indicate that approximately three-quarters of all anthropogenic carbon dioxide emissions currently come from fossil fuel combustion, world energy use has emerged at the center of the climate change debate [***2***].

For some time, fossil fuels have accounted for most of the energy consumed worldwide. Low fossil fuel prices relative to other energy forms have been a major factor underlying this circumstance. In 2000, when world oil prices increased, consumers in many countries were most noticeably affected at the gasoline pump. From an environmental standpoint, the gasoline price increase could be viewed in a positive light: higher prices have the potential to discourage fuel consumption, thereby reducing carbon dioxide and other tailpipe emissions. However, the price increase illustrates the conflict that often arises between energy use (in this case oil consumption) and environmental concerns such as climate change.

The higher gasoline prices of 2000 were generally not well received. In Western Europe, truck drivers, farmers, and taxi drivers launched protests against high motor fuel prices in the fall of 2000. In the United States, efforts to alleviate the temporarily tight market supply and bring down prices prompted support for releasing oil from the Strategic Petroleum Reserve. The recent price spikes also increased calls for opening up parts of the Arctic National Wildlife Refuge in Alaska for oil and gas development as part of a long-term approach to increasing domestic energy supply; but oil drilling in such ecologically sensitive areas has also been opposed on environmental grounds, illustrating the tradeoffs between energy supply and the environment.

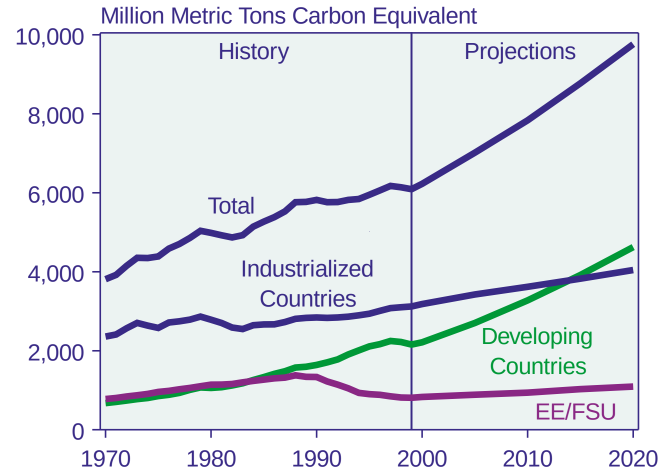
Another environmental issue with implications for world energy markets is the movement of crude oil from source to market. Marine ecosystems are potentially vulnerable to an aging tanker fleet, as evidenced by several recent spills from oceangoing tankers carrying crude oil. In December 1999, the oil tanker Erika broke in half off the coast of Brittany, spilling 3 million gallons of crude oil. In November 2000, more than a half million gallons of crude spilled from a tanker into the lower Mississippi River in Louisiana after an explosion in the tanker's engine caused it to run aground. The U.S. Supreme Court recently rejected an appeal by ExxonMobil against the $5 billion in punitive damages it was ordered to pay after the Valdez tanker ran aground in Alaska in 1989; however, neither public outcry nor threats of litigation have prompted many tanker owners to invest in adjustments (such as double-hull fittings) that would lessen the chances of damaging spills.

Nuclear energy continues to face strong opposition in some areas. Key issues are the safety of nuclear power plant operations, the environmental hazards presented by spent fuel transportation and storage, and the possibility of radioactive releases in the event of nuclear accidents. Austrians protested the startup of a Soviet-designed nuclear power plant in the town of Temelin, Czech Republic, 30 miles from the Austrian border. The nuclear plant began operating in October 2000, despite threats by the Austrian government to block the Czech Republic's entry into the European Union (EU). Concurrently, protests were held in Germany over the lifting of a ban on nuclear waste shipments. The German government imposed the ban 2 years ago when it was revealed that nuclear waste transport containers from past shipments had leaked radiation well above permitted levels. Safety concerns associated with nuclear energy have also been in the spotlight in Japan, the United States, and other countries worldwide.

Global Outlook for Carbon Dioxide Emissions

Carbon dioxide emissions from fossil fuel combustion worldwide increased from 3,811 million metric tons of carbon equivalent in 1970 to 5,821 million in 1990 (Figure 94)—an average annual rate of growth rate of 2.1 percent.[29] Between 1990 and 1999, however, the growth in carbon dioxide emissions slowed to an average annual rate of 0.5 percent per year. Reasons for the slower growth included a 1991 economic recession in the United States that induced a temporary drop in energy use. In Eastern Europe and the former Soviet Union (EE/FSU), political and economic upheaval led to a sharp downturn in energy use that continued through most of the decade. In Western Europe, emissions dropped between 1990 and 1994 as a result of cutbacks in coal use and increasing reliance on nuclear energy. And in the late 1990s, widespread economic recession in Southeast Asia slowed the region's rapidly expanding use of fossil fuels.

Figure 94. World Carbon Dioxide Emissions by Region, 1970-2020



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

Based on expectations of regional economic growth and energy demand in the *IEO2001* reference case, global carbon dioxide emissions are expected to grow more quickly over the projection period than they did during the 1990s. Increases in fossil fuel consumption in developing countries and the EE/FSU are largely responsible for the expectation of fast-paced growth in carbon dioxide emissions. In the EE/FSU and industrialized nations, reductions in non-carbon-emitting nuclear power are expected to lead to corresponding increases in fossil fuel use. Projected increases in natural gas use in Central and South America also contribute to the projected growth of carbon dioxide emissions over the forecast horizon.

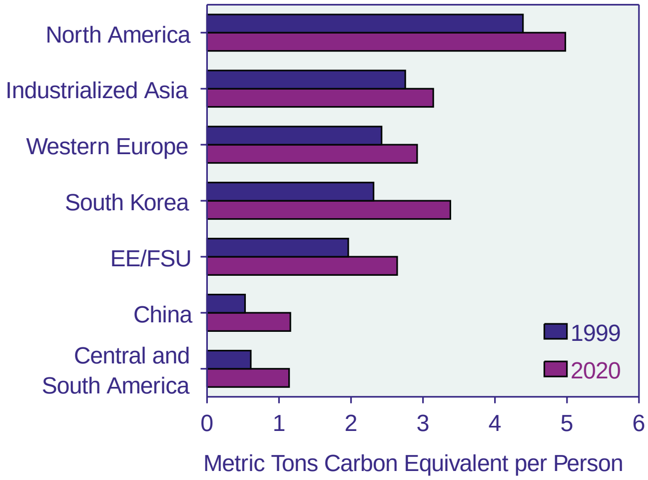
World carbon dioxide emissions are projected to reach 9,762 million metric tons carbon equivalent in 2020, reflecting an increase of 3,671 million metric tons over 1999 emissions. Approximately 67 percent of the growth in emissions between 1999 and 2020 is projected to come from developing countries, where 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 than in industrialized countries. Energy-related emissions in China, the country expected to have the highest rate of growth in per capita income and electricity use over the forecast period, are projected to constitute 28 percent of the global increase in carbon dioxide emissions over the forecast period. In comparison, the industrialized nations are expected to account for 25 percent of the total increase in emissions and the EE/FSU region 8 percent.

In 1999, carbon dioxide emissions from the 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, however, the developing countries are projected to account for the largest share (47 percent) of world carbon dioxide emissions. Still, emissions per capita in the industrialized countries are expected to remain well above the levels in most developing countries, with the exception of South Korea (Figure 95).

Future levels of energy-related carbon dioxide emissions are likely to differ significantly from *IEO2001* projections if measures to stabilize atmospheric concentrations of global greenhouse gases are enacted, such as those outlined under the Kyoto Protocol of the Framework Convention on Climate Change. The Protocol, which calls for limitations on emissions of greenhouse gases (including carbon dioxide) for developed countries and some countries with economies in transition, could have profound effects on future fuel use worldwide. As of February 2001, the Protocol had been ratified by only 32 of the Parties to the United Nations Framework Climate Change Convention (UNFCCC), none of which would be required to reduce emissions under

[29] Carbon dioxide emissions from energy use are reported here in metric tons carbon equivalent. One million metric tons carbon equivalent is equal to 3.667 million metric tons of carbon dioxide.

Figure 95. Per Capita Carbon Dioxide Emissions in Selected Regions and Countries, 1999 and 2020



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

the terms of the treaty.[30] Consequently, *IEO2001* projections do not reflect the potential effects of the Kyoto Protocol or any other proposed climate change policy measures.

Factors Influencing Trends in Energy-Related Carbon Emissions

The *Kaya Identity* is a mathematical expression that is used to describe the relationship among the factors that influence trends in energy-related carbon dioxide emissions:

$$C = (C / E) \times (E / GDP) \times (GDP / POP) \times POP \quad .$$

The formula links total energy-related carbon emissions (*C*) to energy (*E*), the level of economic activity as measured by gross domestic product (*GDP*), and population size (*POP*) [***3***]. The first two components on the right-hand side represent the carbon intensity of energy supply (*C/E*) and the energy intensity of economic activity (*E/GDP*), as discussed below. Economic growth is viewed from the perspective of changes in output per capita (*GDP/POP*). At any point in time, the level of energy-related carbon emissions can be seen as the product of the four Kaya Identity components—energy intensity, carbon intensity, output per capita, and population.

The *carbon intensity of energy supply* is a measure of the amount of carbon associated with each unit of energy produced. It directly links changes in carbon dioxide emissions levels with changes in energy usage. Carbon dioxide emissions vary by energy source, with coal being the most carbon-intensive fuel, followed by oil, then natural gas. Nuclear power and some renewable energy sources (i.e., solar and wind power) do not generate carbon dioxide emissions. As changes in the fuel mix alter the share of total energy demand met by more carbon-intensive fuels relative to less carbon-intensive or “carbon-free” energy sources, overall carbon intensity changes. For example, coal use for electricity generation in Western Europe was increasingly replaced by natural gas and nuclear power during the early 1990s. As a result, the region’s total energy-related carbon dioxide emissions declined more rapidly than its energy use increased, and the overall level of carbon intensity for Western Europe declined steadily during the period.

The *energy intensity of economic activity* is a measure of energy consumption per unit of economic activity. Increased energy use and economic growth generally occur together, although the degree to which they are linked varies across regions and stages of economic development. In industrialized countries, growth in energy demand has historically lagged behind economic growth, whereas the two are more closely correlated in developing countries.

Regional energy intensities, like carbon intensities, may change over time. For example, changes in the overall energy efficiency of an economy’s capital stock (vehicles, appliances, manufacturing equipment, buildings, etc.) affect trends in its energy intensity. Although new stock is often more energy efficient than the older equipment it replaces, the rate of efficiency improvement in an economy is also affected by the availability of more energy-efficient technologies, the rate of capital stock turnover, the dynamics between energy and non-energy prices, investment in research and development, and the makeup of the existing capital stock.

Structural shifts in national or regional economies can also lead to changes in energy intensity, when the shares of economic output attributable to energy-intensive and non-energy-intensive industries change. For example, iron and steel production, chemicals manufacturing, and mining are among the most energy-intensive industrial activities, and countries whose economies rely on production from such energy-intensive industries tend

[30]The Kyoto Protocol will enter into force 90 days after it has been ratified by at least 55 Parties to the UNFCCC, including developed countries representing at least 55 percent of the total 1990 carbon dioxide emissions from this group. The following Parties to the Convention had ratified the Protocol as of February 5, 2001: Antigua and Barbuda, Azerbaijan, Bahamas, Barbados, Bolivia, Cyprus, Ecuador, El Salvador, Equatorial Guinea, Fiji, Georgia, Guatemala, Guinea, Honduras, Jamaica, Kiribati, Lesotho, Maldives, Mexico, Micronesia, Mongolia, Nicaragua, Niue, Palau, Panama, Paraguay, Samoa, Trinidad and Tobago, Turkmenistan, Tuvalu, Uruguay, and Uzbekistan.

to have high energy intensities. When their economies shift toward less energy-intensive activities, their energy intensities may decline. Other influences on regional energy intensity trends include changes in consumer tastes and preferences, taxation, the availability of energy supply, government regulations and standards, and the structure of energy markets themselves.

The Kaya Identity provides an intuitive approach to the interpretation of historical trends and future projections of energy-related carbon dioxide emissions. Essentially, it illustrates how the percentage rate of change in carbon dioxide emission levels over time approximates the percentage rate of change across the four Kaya components.[31] Between 1970 and 1999, both the industrialized world and the developing world had positive annual average growth rates in carbon dioxide emissions, because declines in energy intensity and carbon intensity were outpaced by economic growth and population growth (Table 23). The trend was similar in the EE/FSU region except during the 1990s, when declines in carbon intensity and energy intensity were coupled with a severe drop in economic output per capita. Carbon emissions in the EE/FSU region declined by an average of 5.4 percent per year during the 1990s.

In the *IEO2001* reference case projections for regional carbon dioxide emissions, economic growth and population growth continue to overshadow expected reductions in energy intensity and carbon intensity, particularly in the developing world. Accordingly, future reductions in carbon emissions would require accelerated declines in energy intensity and/or carbon intensity (for example, by increasing the share of energy demand met by low-carbon or carbon-free energy sources). Such changes may in turn require significant changes in existing energy infrastructures. The Kaya Identity does not provide a framework for estimating economic costs associated with any efforts to reduce either carbon intensity or energy intensity.

Table 23. Average Annual Percentage Change in Carbon Dioxide Emissions and the Kaya Identity Components by Region, 1970-2020

Parameter	History			Reference Case Projections	
	1970-1980	1980-1990	1990-1999	1999-2010	2010-2020
Industrialized World					
Carbon Intensity	-0.5%	-0.7%	-0.5%	0.0%	0.1%
Energy Intensity	-1.1%	-2.0%	-0.7%	-1.3%	-1.3%
Output per Capita	2.4%	2.2%	1.6%	2.2%	2.0%
Population	0.9%	0.7%	0.6%	0.5%	0.4%
Carbon Emissions	1.7%	0.2%	1.0%	1.4%	1.1%
Developing World					
Carbon Intensity	-0.8%	-0.2%	-0.7%	-0.1%	-0.1%
Energy Intensity	-0.4%	0.9%	-1.0%	-1.4%	-1.4%
Output per Capita	3.5%	1.7%	3.1%	3.7%	4.2%
Population	2.2%	2.1%	1.7%	1.7%	0.8%
Carbon Emissions	4.6%	4.5%	3.1%	3.9%	3.5%
Eastern Europe and the Former Soviet Union					
Carbon Intensity	-0.8%	-0.3%	-1.0%	-0.2%	-0.3%
Energy Intensity	1.4%	0.6%	-0.5%	-2.4%	-2.6%
Output per Capita	2.4%	0.6%	-4.0%	4.1%	4.5%
Population	0.9%	0.7%	0.0%	0.0%	0.0%
Carbon Emissions	3.9%	1.6%	-5.4%	1.4%	1.5%

Note: Using an average annual rate of change in carbon emissions between any two years mathematically approximates the actual combined effect on emission levels from changes in the four Kaya Identity components. Across years where there were large changes in either carbon emission levels or the Kaya Identity components themselves, comparisons based on an average annual rate of change measure may yield round-off differences.

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, January 2001). **Projections:** EIA, World Energy Projection System (2001).

[31] In terms of rates of changes, the Kaya Identity can be expressed as $[d(\ln C)\ /\ dt = d(\ln C/E)\ /\ dt + d(\ln E\ /\ GDP)\ /\ dt + d(\ln GDP\ /\ POP)\ /\ dt + d(\ln POP)\ /\ dt]$, which shows that, over time, the rate of change in carbon emissions is equal to the sum of the rate of change across the four Kaya components (i.e. the rate of change in carbon intensity, plus the rate of change in energy intensity, plus the rate of change in output per capita, plus the rate of change in population).

Regional Trends

Industrialized Countries

In the industrialized world, half of all energy-related carbon dioxide emissions in 1999 came from oil use, followed by coal at 30 percent. Oil is projected to remain the primary source of carbon dioxide emissions in the industrialized countries throughout the projection period because of its continued importance in the transportation sector, where there are currently few economical alternatives. Natural gas use and associated carbon dioxide emissions are projected to increase substantially between 1999 and 2020 (Figure 96), particularly in the electricity sector.

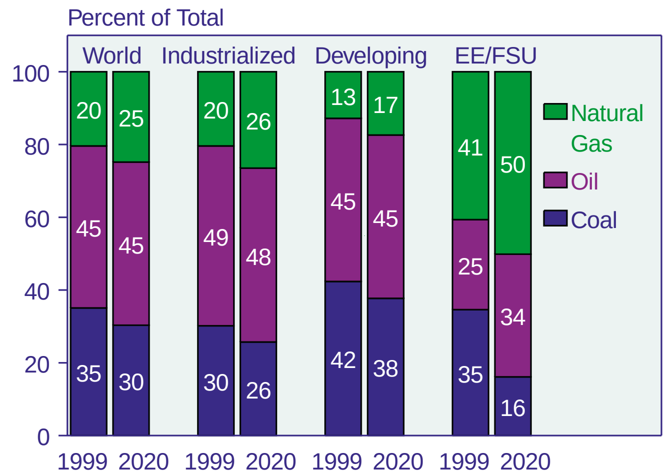
Energy-related carbon dioxide emissions from the United States accounted for approximately one-half of the carbon emissions from industrialized countries throughout the 1990s. U.S. carbon dioxide emissions increased steadily over the decade (with the exception of 1991). In Western Europe, carbon dioxide emissions dropped between 1990 and 1994, largely as a result of decreasing coal consumption in Germany and the United Kingdom. In Japan, emissions fell after 1996, when a major economic slowdown and recession led to reductions in energy use (Figure 97). Given expectations for economic growth over the forecast period (including Japan, whose economy is expected to recover), carbon dioxide emissions from the industrialized world are projected to increase at a faster pace than during the 1990s.

North America

In North America, strong economic growth was the main factor underlying the growth in energy consumption and carbon dioxide emissions during the 1990s. The United States held a steady 84-percent share of the continent's total energy consumption during the 1990s. U.S. carbon intensity is projected to increase in the *IEO2001* reference case, primarily because of expected changes in the fuel mix for electricity generation. Natural gas and coal use for electricity generation are projected to increase, whereas generation from nuclear energy is expected to decline toward the end of the forecast period with the retirement of some nuclear power capacity. As a result, U.S. electricity generation is projected to become more carbon intensive over the forecast period. In total, annual energy-related carbon dioxide emissions in the United States are projected to increase by about 35 percent between 1999 and 2020, with fossil fuel use for electricity generation and transportation expected to continue as the source of most of the country's energy-related carbon dioxide emissions.

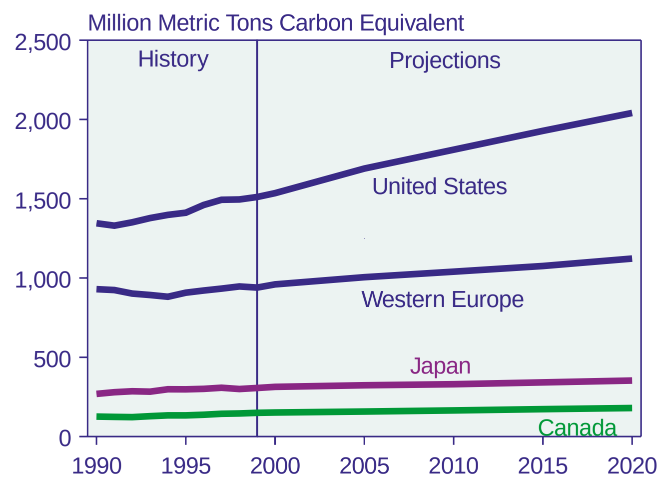
Canada accounted for 11 percent of North America's energy use during the 1990s. Energy use in Canada has been less carbon-intensive than in the United States

Figure 96. 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, January 2001). **2020:** EIA, World Energy Projection System (2001).

Figure 97. Carbon Dioxide Emissions in the Industrialized World, 1990-2020



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

(Table 24). In the 1990s, Canada relied on renewable energy sources (predominantly hydroelectric power) to meet approximately 30 percent of its total energy demand, as compared with 7 to 8 percent in the United States. Canada also has significant fossil fuel reserves, but coal, the most carbon-intensive fossil fuel, accounts for a smaller share of energy use in Canada than it does in the United States.

In Canada's electric power sector, hydropower accounted for 62 percent of the total energy consumed for electricity generation in 1999 and nuclear power 14 percent. Fossil-fired generation capacity is expected to

Table 24. Carbon Intensities of Energy Use for Selected Countries and Regions, 1990, 1999, 2010, and 2020
(Million Metric Tons Carbon Equivalent per Quadrillion Btu)

Country or Region	1990	1999	2010	2020
United States	16.02	15.62	15.85	16.06
Canada	11.57	11.67	10.75	10.81
Mexico	16.81	16.40	16.63	16.98
United Kingdom	17.86	15.49	15.87	15.78
Germany	18.33	16.45	15.90	15.84
France	11.00	9.94	9.56	9.82
Japan	15.02	14.12	14.04	13.61
Australasia	18.15	18.46	18.07	17.83
Former Soviet Union	16.97	15.46	15.35	15.35
Eastern Europe	19.65	18.00	16.41	14.36
China	22.85	20.92	20.44	20.01
India	19.67	19.88	19.05	18.23
South Korea	16.57	14.63	14.01	13.29
Middle East	17.63	17.07	16.76	16.86
Africa	19.21	18.50	18.19	17.93
Central and South America	12.97	12.62	13.29	13.85

Sources: **1990 and 1999:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **2010 and 2020:** EIA, World Energy Projection System (2001).

increase over the projection period as more natural-gas-fired capacity is added and aging nuclear power plants are shut down, but Canada's overall carbon intensity is not expected to change significantly. The 20-percent projected growth in energy-related carbon dioxide emissions in Canada is largely attributable to expected strong economic growth.

Mexico had the smallest share of North America's energy use and energy-related carbon dioxide emissions during the 1990s, although its carbon intensity was somewhat higher than that in the United States. As a major non-OPEC oil producer, Mexico's overall energy mix and electricity generating portfolio have relied heavily on oil. Natural gas is the next most important source of overall energy consumption, although its market share is less than renewables (principally hydropower) in terms of energy consumed for electricity generation.

With a projected rate of economic growth that is higher than for any other country in the industrialized world and an expected rate of decline in energy intensity that is comparable with those for most of the other industrialized countries, Mexico's carbon dioxide emissions are expected to increase at the region's fastest rate. Average annual increases of 3.4 percent are projected as carbon dioxide emissions rise from 101 million metric tons carbon equivalent in 1999 to 203 million in 2020. Nevertheless, Mexico still is expected to account for less than one-tenth of North America's total energy-related carbon dioxide emissions.

Western Europe

Energy-related carbon dioxide emissions in Western Europe are projected to increase from 940 million metric tons carbon equivalent in 1999 to 1,123 million metric tons carbon equivalent in 2020. The region's overall carbon intensity declined on average by 1 percent per year from 1990 to 1999 as a significant portion of its energy use shifted from coal to natural gas and nuclear energy. During the same period, total energy consumption increased by 1.1 percent per year. Consequently, there was almost no net change in the region's carbon dioxide emissions from 1990 to 1999.

The decline in Western Europe's coal consumption is projected to continue in the *IEO2001* forecast as natural gas consumption, particularly for electricity generation, increases. Renewable energy use is also projected to increase, but decreases in nuclear power generation over the forecast period are projected to slow the decline in carbon intensity. Germany's new coalition government recently committed to a complete phaseout of domestic nuclear power generation, with the last plant closure expected to occur in the mid-2020s [***4***]. Belgium, Sweden, the Netherlands, and Spain have also committed to shutting down their nuclear power industries.

Industrialized Asia

Japan, the world's second largest economy and fourth largest energy consumer, was responsible for most of industrialized Asia's carbon dioxide emissions in the 1990s, although its carbon intensity ranked at the low end among industrialized countries (along with France and Canada), primarily due to its continued reliance on nuclear energy for reasons of national energy security. Nuclear energy represented 33 percent of Japan's electricity consumption in 1999, up by 6 percentage points from 1990. Over the forecast period, Japan's carbon dioxide emissions are projected to increase by 15 percent as a result of increasing energy demand (prompted by a gradual upswing in economic growth) and increasing carbon intensity. Although the government plans to increase nuclear generation, natural gas is expected to capture a larger share of the fuel market for electricity generation and for other uses.

In contrast to Japan, Australasia had one of the highest carbon intensities in the industrialized world, at approximately 18 million metric tons carbon equivalent per quadrillion Btu throughout most of the 1990s. Patterns of energy use vary across this region, which includes Australia, New Zealand, and the U.S. Territories. Australia accounts for the majority of Australasia's energy consumption, and with large domestic fossil fuel reserves, it has relied heavily on coal and oil to meet its energy needs. Australasia's energy consumption is expected to increase steadily over the forecast period. A slight decline in carbon intensity is expected, with natural gas use growing more rapidly than coal use. Overall, however, Australasia's energy-related carbon dioxide emissions are projected to increase by 25 percent, to 144 million metric tons carbon equivalent in 2020.

Eastern Europe and the Former Soviet Union

Energy consumption and carbon dioxide emissions in the EE/FSU region have declined significantly in the wake of political and economic changes since 1990. For most countries in the region, the transition to a market-oriented economy has been accompanied by lower industrial activity and per capita income. The FSU countries encountered further economic setbacks as a result of the 1998 Russian financial crisis and civil conflicts in Russia and other countries in the Commonwealth of Independent States. Between 1990 and 1999, energy consumption declined by 27 percent in Eastern Europe and by 36 percent in the FSU. The concomitant declines in carbon dioxide emissions in the two regions were slightly greater (33 percent and 41 percent, respectively), because their carbon intensities also decreased. Coal production and consumption in the EE/FSU declined as a result of economic reforms and industry restructuring, and the natural gas and nuclear shares of the energy mix increased.

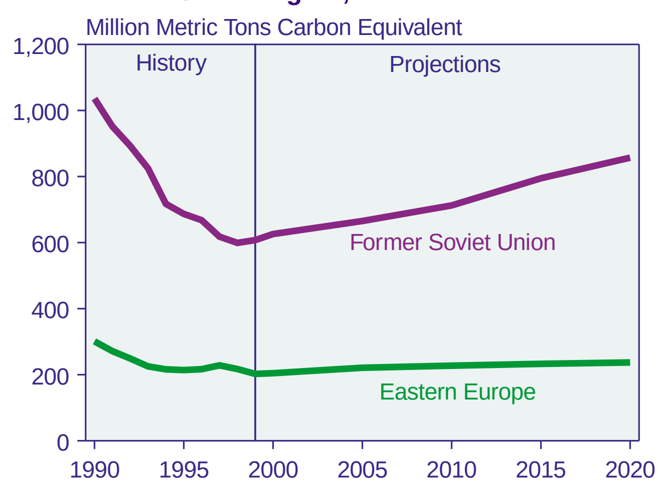
Given the expectations for economic recovery in the FSU and further economic expansion in Eastern Europe, energy consumption and carbon dioxide emissions in the EE/FSU region are projected to increase over the forecast period. The majority of the projected increase in EE/FSU emissions is expected in the FSU, where carbon intensity is projected to remain largely unchanged. With the further development of the vast natural gas reserves in Russia and the Caspian Sea region, natural gas is expected to continue to displace coal use in the FSU, but carbon-intensive oil consumption is also expected to increase, and nuclear energy use is expected to decline as Soviet-era nuclear reactors are retired. Total carbon dioxide emissions in the FSU are projected to increase by 250 million metric tons carbon equivalent between 1999 and 2020, but at 857 million metric tons carbon equivalent in 2020 they would still be lower than the 1990 level of 1,036 million metric tons carbon equivalent (Figure 98).

In Eastern Europe, coal accounted for 40 percent of the overall fuel mix and 56 percent of the energy consumed for electricity generation in 1999. With further restructuring of the coal mining industry in Poland and the Czech Republic, declines in coal production and consumption are expected to continue. Between 1999 and 2020, natural gas use is projected to more than triple, whereas coal consumption is projected to decline by half. As a result, the region's carbon intensity is expected to decline by 20 percent—more than in any other region of the world. Even at that rate, however, the decline in Eastern Europe's carbon intensity would not keep pace with the expected growth in total energy consumption (47 percent). Consequently, carbon dioxide emissions in the region are expected to increase from 203 million metric tons carbon equivalent in 1999 to 237 million in 2020.

Developing Countries

In the developing countries, carbon dioxide emissions from the combustion of all fossil fuels are projected to increase, although emissions from the combustion of

Figure 98. Carbon Dioxide Emissions in the EE/FSU Region, 1990-2020



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

coal and oil are expected to grow more slowly than those from natural gas. Coal is expected to remain a major source of energy-related carbon emissions in the developing world, most notably in China and India, where heavy reliance on coal consumption is projected to continue throughout the projection period. Nevertheless, coal's share of total carbon dioxide emissions in the developing world is projected to decline from 42 percent in 1999 to 38 percent in 2020. The oil share is expected to remain steady at 45 percent, and the natural gas share is expected to increase from 13 percent to 17 percent.

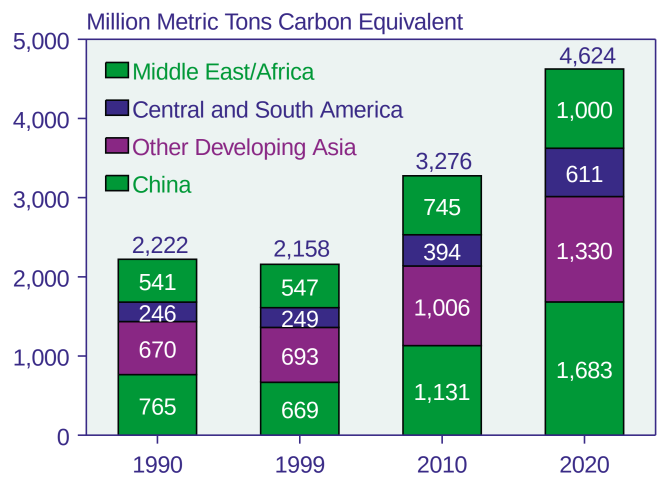
Carbon dioxide emissions in the developing world increased at a robust rate throughout most of the 1990s as a result of rapid economic expansion, growing demand for energy, and relatively minor decreases in carbon intensity. Overall, energy consumption increased by 40 percent between 1990 and 1999, and carbon dioxide emissions increased by 31 percent. Most of the growth in energy use and carbon dioxide emissions in the developing world occurred in Asia. Despite the economic recessions that followed the Asian financial crisis of 1997, average annual rates of economic growth in the nations of developing Asia were higher than in any other region during the 1990s. Continued economic growth and population growth over the forecast period are projected to further increase energy consumption in the developing world, particularly coal use for electricity generation and oil consumption for transportation services. As a result, in the *IEO2001* reference case carbon dioxide emissions in the developing world are projected to more than double, from 2,158 million metric tons carbon equivalent in 1999 to 4,624 million in 2020 (Figure 99).[32]

Currently, carbon intensities in developing Asia rank highest among the developing countries and on a worldwide basis. China and India rely heavily on domestic supplies of coal for electricity generation and industrial activities, the emissions from which have contributed to the worsening of air quality in those countries. In 1999, coal accounted for 61 percent of total energy consumption in China and 52 percent in India, with the remaining share of energy consumption in each country dominated by oil. As a result, their carbon intensities were 21 and 20 million metric tons carbon equivalent per quadrillion Btu, respectively. Because oil rather than coal is the predominant fuel consumed in South Korea and other developing areas of Asia, their carbon intensities were somewhat lower than those for China and India.

Based on expectations of continued economic expansion and population growth in developing Asia, energy consumption in developing Asia is projected to more than double between 1999 and 2020. The projection for developing Asia's carbon dioxide emissions follows suit. In China, where coal reserves are abundant and access to other energy fuels is limited in many parts of the country, coal is expected to continue to be the primary source of energy. India's carbon intensity is projected to decline more rapidly than China's due to a more pronounced shift away from coal. The use of natural gas, nuclear energy, and renewables for electricity generation is projected to increase significantly in India, although coal consumption is still expected to represent a large share of total energy consumption, particularly in India's heavy industry sector. Coal's share of total energy consumption is also projected to decline in South Korea and other developing Asia as natural gas use increases.

In Central and South America, carbon intensity was relatively low in the 1990s because hydropower fueled the majority of the region's electricity generation. In 1999, renewable energy sources (primarily hydropower) accounted for 94 percent of the energy consumed for electricity generation in Brazil and 59 percent in other Central and South America. Over the forecast period, carbon intensity in Central and South America is projected to increase as a result of efforts to lessen dependence on hydropower. Carbon dioxide emissions in the region are projected to increase by 4.4 percent per year on average between 1999 and 2020, while energy consumption is projected to grow at a slightly slower pace.

Figure 99. Carbon Dioxide Emissions in the Developing World, 1990, 1999, 2010, and 2020



Sources: **1990 and 1999:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **2010 and 2020:** EIA, World Energy Projection System (2001).

[32]Compared with the industrialized world, a much larger share of energy consumption in the developing world (especially Africa and Asia) comes from biomass—including wood, charcoal, and agricultural residues. Because data on biomass use in developing countries are often sparse or inadequate, *IEO2001* does not include the combusion of biomass fuels in its coverage of current or projected energy consumption.

Environmental Impacts of Hydropower

It is estimated that approximately one-third of the countries in the world currently rely on hydropower for more than half of their electricity supply. Largely considered a “clean” renewable energy source, hydropower has provided many economic and social benefits. Many countries have chosen to develop their hydroelectric resources as a means of improving domestic energy security, providing more energy services, stimulating regional economic development, and increasing economic growth. For example, Brazil started to invest heavily in hydroelectric development in the 1970s, after experiencing the world oil price shocks and their effects on national energy supply and, particularly, electricity costs. Hydroelectric development in Brazil, which has resulted in some of the world’s largest hydropower plants, bolstered growth in the country’s heavy industry sector and helped achieve a high level of electrification.

The benefits provided by hydroelectric development in Brazil and other countries were not achieved without also incurring some negative economic, social, and environmental impacts. In particular, large hydroelectric facilities have tended to demonstrate variable economic performance, and in some cases they have been blamed for increasing the debt burden of developing countries. Most of the negative social and environmental impacts are associated with hydroelectric reservoirs (as well as reservoirs and dams for other purposes), rather than hydropower itself.

It is now widely recognized that dam development, whether for hydropower or other purposes, can disrupt the culture and sources of livelihood of many communities. Studies have indicated that the majority of the people uprooted from their existing settlements as a result of dam development are poor and / or members of indigenous populations or vulnerable ethnic minorities. Displaced populations are also more likely to bear a disproportionate share of the social and environmental costs of large dam projects without gaining a commensurate share of the economic benefits. The negative environmental impacts of dams and their reservoirs include loss of forests, wildlife habitats, species populations, aquatic biodiversity, upstream and downstream fisheries, and services provided by downstream flood plains and wetlands.[a]

With the emergence of climate change as an environmental issue of increasing international concern, hydropower has largely been viewed as a “cleaner” energy source than fossil fuels. No carbon dioxide or other greenhouse gas emissions result from the generation of hydroelectricity, because no fuel combustion is involved. However, results from preliminary field studies indicate that the reservoirs associated with hydroelectric dams emit both carbon dioxide and methane. Emissions emanate from the decomposition of biomass in the reservoirs and from biomass flowing in from the river’s catchment area. The scale of emissions is variable, depending on the reservoir location (geography, altitude, latitude), temperature, size, depth, depth of turbine intakes, dam operations, and construction procedures.[b] Additional greenhouse gases are also emitted in the process of making cement for dam construction.

The recently discovered evidence of hydroelectric-related greenhouse gas emissions has obvious implications for energy choices made in light of climate change considerations. Some field studies suggest that greenhouse gas emissions from hydroelectric reservoirs (the sum of carbon dioxide and methane, based on their global warming potentials) can be similar in magnitude to those from thermal power plants with equivalent generation capacity. (Because specific site conditions determine the levels of emissions from hydroelectric reservoirs, comparisons must be made on a case-by-case basis.) On the other hand it has been argued that the true measure of “anthropogenic” emissions associated with a hydroelectric plant can only be assessed by comparison with emissions from the same catchment area before the dam was constructed.[a]

[a]World Commission on Dams, *Dams and Development: A New Framework for Decision-Making* (London, UK: Earthscan Publications, 2000).

[b]World Commission on Dams, “Hydropower and Climate Change: WCD Reviews Evidence on Large Dams and Greenhouse Gas Emissions,” Press Release (June 10, 2000), web site www.dams.org.

In 1999, carbon intensities in Africa and the Middle East—at 19 and 17 million metric tons carbon equivalent per quadrillion Btu, respectively—were close to the average for the developing world. Oil was the most widely used fuel in both regions, although Africa relied more extensively on coal for electricity generation. In both regions, coal consumption is expected to decline relative to oil consumption over the forecast period, resulting in similarly slight decreases in carbon intensity. Carbon dioxide emissions are expected to grow more rapidly in the Middle East than in Africa, due to the higher projected rate of growth for energy demand in the Middle East.

Issues in Climate Change Policy

The Framework Convention on Climate Change

To date, the world community's effort to address global climate change has taken place under the auspices of the United Nations Framework Convention on Climate Change (UNFCCC), which was adopted in May 1992 and entered into force in March 1994. The ultimate objective of the UNFCCC is "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" [***5***]. The most ambitious proposal coming out of the subsequent conferences of the parties has been the Kyoto Protocol, which was developed by the third conference of the parties (COP-3) in Kyoto, Japan, in December 1997. 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 for most countries covered under the Protocol.[33]

In addition to domestic emission reduction measures, the Kyoto Protocol allows four " flexibility mechanisms" to be used by Annex I countries in meeting their emission targets:

- *International emissions trading* allows Annex I countries to transfer some of their allowable emissions to other Annex I countries, beginning in 2008. For example, an Annex I country that reduces its 2010 greenhouse gas emissions level by 10 million metric tons carbon equivalent more than needed to meet its target level can sell the "surplus" emission reductions to other Annex I countries. The trade would lower the seller's allowable emissions level by 10 million metric tons carbon equivalent and raise the buyers' allowances by the same amount.

- *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, European Union (EU) countries have adopted a burden-sharing agreement that reallocates the aggregate Kyoto emission reduction commitment for the EU among the member countries [***6***].

- *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 CDM, except that the investment in emission reduction projects occurs in Annex I countries.

The Kyoto targets refer to overall greenhouse gas emission levels, which encompass emissions of carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. Hence, a country may opt for relatively greater reductions of other greenhouse gas emissions and smaller reductions of carbon dioxide, or vice versa, in order to meet its entire Kyoto obligation. Currently, it is estimated that carbon dioxide emissions account for a large majority of overall greenhouse gas emissions in most Annex I countries, followed by methane and nitrous oxide[***7***].

The Kyoto Protocol also looks beyond energy-related sources of carbon dioxide.[34] 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 addressed under the Protocol. While the conference of the parties is still working to reach a consensus on an equitable accounting method for sinks, the Protocol could allow emission reductions resulting from actions such as reforestation to serve as an alternative means for a country to achieve its overall Kyoto commitment.[35] The extent to which each Annex I country makes use of the Kyoto mechanisms will also influence the amount of domestic emission reductions needed to comply with the Protocol.

IEO2001 projects only emissions of energy-related carbon dioxide, which, as noted above, account for the bulk of Annex I emissions. The *IEO2001* reference case projections indicate that energy-related carbon dioxide emissions from the Annex I countries will exceed the group's 1990 emissions level by 10 percent in 2010. Industrialized Annex I countries emitted 3,022 million metric tons carbon equivalent from energy use in 1999 and are projected to emit 3,475 million metric tons by 2010. Taking the prescribed Kyoto emission reduction targets on the basis of energy-related carbon dioxide emissions alone,

[33]Turkey and Belarus, which are represented under Annex I of the UNFCCC, do not have quantified emission targets under the Kyoto Protocol. The Protocol does include emission targets for 4 countries not listed under Annex I (Croatia, Liechtenstein, Monaco, and Slovenia). Collectively, the 39 Parties (38 countries plus the European Union) with specific emissions targets under the Kyoto Protocol are referred to as "Annex B Parties," because their targets are specified in Annex B of the Protocol.

[34]Annex A of the Kyoto Protocol lists all the sector and source categories for all greenhouse gas emissions covered under the agreement.

[35]Article 3.3 of the Kyoto Protocol allows Annex I Parties to count toward their emission targets net changes in greenhouse gas emissions resulting specifically from afforestation, reforestation, and deforestation since 1990. Article 3.4 leaves the door open for the inclusion of other land use and forestry activities that release (emit) or remove (uptake) greenhouse gases.

the industrialized Annex I countries would face an emission limit of 2,573 million metric tons carbon equivalent in 2010—a 26-percent difference from their projected baseline emissions[36] (Figure 100). 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 reach 802 million metric tons carbon equivalent in 2010, still 30 percent below their combined Kyoto reduction target.

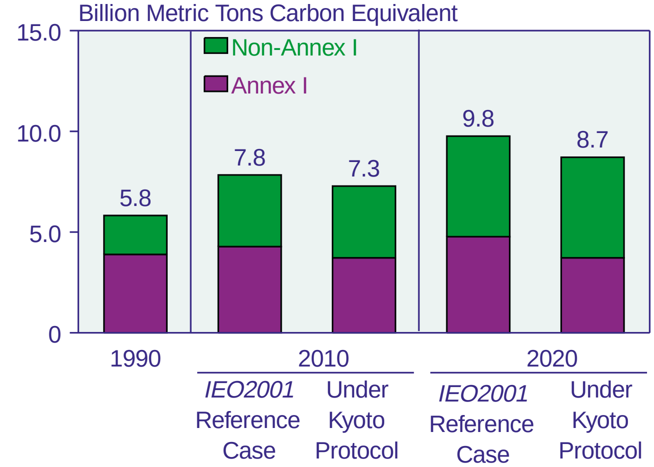
Details regarding the operation of the Kyoto Protocol have been the subject of several UNFCCC meetings since COP-3. In November 1998, COP-4 took place in Buenos Aires, Argentina, where delegates determined a schedule, called the Buenos Aires Plan of Action, for reaching agreement on precisely how the Protocol is to operate. Among the more contentious topics of negotiation were the regime for monitoring compliance with emission reduction commitments, the treatment of terrestrial greenhouse gas sinks, and rules governing the use of the Kyoto flexibility mechanisms.

The Buenos Aires Plan of Action set COP-6 as the deadline for resolving the operational details of the Kyoto Protocol. However, the COP-6 negotiations, which took place in November 2000 in The Hague, the Netherlands, ended without agreement. Rather than concluding negotiations without a resolution, the UNFCCC delegates agreed to suspend COP-6 and to reconvene in the summer of 2001.

National and Regional Greenhouse Gas Emissions Trading

Despite the current uncertainty about the fate of the Kyoto Protocol, several countries are establishing or considering domestic programs specifically aimed at reducing their own greenhouse gas emissions from energy use. The programs are diverse in coverage and approach, ranging from government-sponsored incentive programs to encourage voluntary emissions reductions by industry or geographic region to mandatory carbon tax schemes for lowering carbon-intensive energy use. In some countries, domestic emission trading schemes are being developed either independently or as a part of wider emission abatement programs. For the most part, the emission trading schemes use a "cap and trade" approach consistent with international emissions trading under the Kyoto Protocol, similar to the sulfur dioxide emissions trading program already in effect in the United States (see box on page 170).

Figure 100. 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, January 2001). **2010 and 2020:** World Energy Projection System (2001).

In 1999, Denmark became the first European country to establish its own emissions trading program, targeting carbon dioxide emissions from its electricity sector. The program was included as part of a larger electricity reform package that the Danish government developed in order to implement EU directives on electricity and gas market liberalization. The trading program, in conjunction with other energy-related initiatives, is intended to help Denmark meet its own national target of reducing carbon dioxide emissions to 20 percent below 1988 levels by 2005.[37] The trading program was originally scheduled to operate between 2000 and 2003, with the entire electricity sector facing an emissions cap of 23 million metric tons carbon equivalent in 2000, descending to 20 million metric tons in 2003. Issues related to electricity sector competition delayed the European Commission's approval of Denmark's reform package until May 2000, however, and the Danish government pushed back the start date for the carbon trading scheme to 2001.

In November 2000, the United Kingdom announced a new Climate Change Programme that incorporated a variety of policies geared toward reducing the country's overall greenhouse gas emissions to 23 percent below 1990 levels by 2010 [***8***]. Among other policies included in the UK's Climate Change Programme is a "climate change levy" (tax) on the energy content of natural gas, coal, and electricity used by businesses and public entities, starting on April 1, 2001. Government revenues

[36]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.

[37]*Energy 21* is the action plan the Danish government put forward in 1996 to achieve by 2005 a 20-percent reduction in its total carbon dioxide emissions from their 1988 level. See web site www.ens.dk/uk/index.asp for further details on Danish energy policy and reforms.

Reducing Sulfur Dioxide and Nitrogen Oxide Emissions in the European Union and the United States

Many countries currently have policies or regulations to limit energy-related emissions of sulfur dioxide and nitrogen oxides. Both pollutants are known to contribute to the problems of acid rain and eutrophication of soils and waters, and nitrogen oxides also contribute to the formation of smog caused by ground-level (tropospheric) ozone. Coal-fired electricity generation both in the United States and in the European Union (EU). Electricity generation is also a source of nitrogen oxide emissions, but oil use for transportation is the largest source.

In Europe, efforts to limit sulfur dioxide and nitrogen oxide emissions were first coordinated under the 1979 United Nations/Economic Commission of Europe 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 in 1983, the Convention has been extended by eight protocols, setting emissions limits for a variety of pollutants. The most recent protocol, the 1999 Gothenburg Protocol to Abate Acidification, Eutrophication, and Ground-Level Ozone, sets new national emissions ceilings for sulfur dioxide, nitrogen oxides, volatile organic compounds, and ammonia.

The national emissions ceilings under the Gothenburg Protocol correspond to a target reduction of total sulfur dioxide emissions in the EU of 75 percent below the 1990 level by 2010 and a 50-percent reduction in its nitrogen oxide emissions from the 1990 level by 2010.[a] Like the earlier CLRTAP protocols, the Gothenburg Protocol specifies tight limit values for specific emissions sources, based on the concept of critical loads, and requires best available technologies to be used to achieve the emissions reductions.

More specific measures for abating sulfur dioxide and nitrogen oxide emissions are defined in a number of European Commission directives. The Large Combustion Plant Directive of 1988 and its amendments impose sulfur dioxide and nitrogen oxide emission limits on existing and new plants with a rated thermal input capacity greater than 50 megawatts and sulfur dioxide emissions limits on smaller combustion plants using solid fuels (particularly coal). Other directives impose limits on the sulfur content of certain fuels used in power stations, industry, and motor vehicles; requirements for the use of best available technologies on new and existing plants (e.g., flue gas desulfurization devices, low nitrogen oxide burners); and vehicle emissions standards.

Since 1980, sulfur dioxide and nitrogen oxide emissions in Europe have fallen. The drop in sulfur dioxide emissions was partly due to prescribed emissions limits and technology requirements, particularly in the electricity generation sector. Shifts from coal to natural gas for electricity production in several countries during the 1990s (most notably in Germany and the United Kingdom) also contributed to the reduction. The same factors also contributed to the drop in nitrogen oxide emissions, but the introduction of catalytic converters on vehicles was the most influential factor.[b]

In the United States, initiatives to reduce sulfur dioxide and nitrogen oxide emissions stem from the Clean Air Act, the comprehensive Federal law that regulates air emissions from area, stationary, and mobile sources. The 1970 and 1977 Clean Air Act Amendments included emissions standards and requirements for the use of best available control technologies for new sources. The 1990 Amendments set emissions reduction goals for specific air pollutants and designated

(continued on page 171)

[a]For specific emission targets by country, see Annex II of the Gothenburg Protocol, web site www.unece.org.
[b]European Environment Agency, *Environmental Signals 2000* (Copenhagen, Denmark, 2000), web site www.eea.eu.it.

from the levy are to be recycled through a "carbon trust" that makes investments in alternative energy, energy-saving technologies, and other related programs. In the energy-intensive industries, large consumers will be offered an 80-percent rebate of the levy if they negotiate an agreement with the government for meeting an energy efficiency standard or absolute energy use cap. The negotiated standards and caps will be stated in terms of their associated carbon dioxide emission levels, essentially reflecting an emissions allowance for each firm. Under a proposed emissions trading scheme, the businesses that negotiate levy agreements will be able to trade their emission allowances. The government expects emissions trading to begin in April 2001.

Norway, which has had a carbon dioxide tax scheme on energy use in place since 1991, recently developed a comprehensive domestic emissions trading system that covers carbon dioxide and other greenhouse gas emissions from a wide variety of sources. The proposed Norwegian trading system is set to begin in 2008. If the Kyoto Protocol comes into force, Norway's trading system will be open to tradable emission allowances from other Annex I parties and to certified emission reduction credits originating from the Kyoto clean development mechanism.

France, Germany, Sweden, and the Netherlands have indicated a desire to establish some form of domestic

Reducing Sulfur Dioxide and Nitrogen Oxide Emissions (Continued)

stricter emissions standards extending across a wider range of sources.

Title IV of the Clean Air Act Amendments of 1990 (CAAA90) was intended to reduce the adverse effects of acid deposition by setting 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. To achieve the sulfur dioxide reductions, a two-phase tightening of emissions restrictions was placed on existing fossil-fired power plants serving utility generators with an output capacity greater than 25 megawatts and on all new utility units. Phase I, which began in 1995, affected mostly coal-burning electric utility plants in 21 eastern and southern States. Phase II, which began in 2000, tightened the annual emissions limits imposed on those large, higher emitting plants and also placed restrictions on smaller, cleaner plants fired by coal, oil, and gas.

CAAA90 Title IV established the world's first large-scale application of a "cap and trade" program to meet an environmental goal. Under the program, a total annual emissions budget (measured in tons of sulfur dioxide) was established for each year, in accordance with aggregate emissions reduction goals. Generating units were issued tradable emission allowances, based primarily on their historic fuel consumption and specific emissions rates. Each allowance permits a generating unit to emit one ton of sulfur dioxide during or after a given year. At the end of each year, power plant owners must hold an allowance for each ton of sulfur dioxide emitted that year, or else face a penalty. Extra allowances may be bought, sold, or banked (i.e., saved for future use rather than for current use).

Emissions data from Phase I indicate overcompliance: the generating units subject to the Phase I emissions cap emitted, in aggregate, less sulfur dioxide than the total allowable level. Emissions were reduced by a combination of strategies, including the installation of scrubbers, switching to low-sulfur coal, and trading emission allowances.[c] It is argued that without the trading option, the reduction in sulfur dioxide emissions that was over and above the required amount would not have been as large.[d] Phase II of the program, which is currently in effect, sets a permanent ceiling (cap) of 8.95 million tons on the allowances issued each year; however, the amount of sulfur dioxide actually emitted may exceed the Phase II cap for some time, because allowances banked under Phase I can be carried over to Phase II.

The nitrogen oxide emissions reductions required by CAAA90 Title IV were also scheduled according to a two-phase approach, but no cap was set for aggregate nitrogen oxide emissions from electricity generation, and no allowance trading program was included. Phase I, which began in 1996, set an emissions limit (in pounds of nitrogen oxide per million Btu of fuel input) for two types of coal-fired utility boilers already targeted for Phase I sulfur dioxide emissions reductions. Phase II, which started in 2000, set stricter nitrogen oxide emissions limits for those boiler types and established emissions limits for other coal-fired boiler types.

Other programs for reducing nitrogen oxides and sulfur dioxide emissions in the United States have been established as a result of the Clean Air Act Amendments. In an effort to reduce the transport of emissions over long distances and help States meet the national ambient air quality standards for ground-level ozone, 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 new rules, commonly referred to as the "NO_x SIP Call," require abatement efforts greater than those required to comply with the limits on nitrogen oxides under CAAA90 Title IV. The limits under the NO_x SIP Call have been set in the form of allowances and allowance trading is permitted.

CAAA90 also established emissions standards for motor vehicles. "Tier 1" standards cover emissions of nitrogen oxides (in addition to carbon monoxide, hydrocarbons, and particulate matter) for light-duty vehicles beginning with model year 1994, and the tighter "Tier 2" standards, which apply to all passenger vehicles, will be phased in starting in 2004. Tier 2 standards also require that the sulfur content of gasoline be reduced, in order to ensure the effectiveness of the emission control technologies that will be needed to meet the emission targets. Heavy-duty vehicles (trucks) have also faced emissions standards since 1990, which were easily met by engine controls. Recent rulings impose a new "ultra-low" sulfur content requirement for diesel fuel used by highway trucks and specific nitrogen oxide emissions control technologies by 2007.

[c]International Energy Agency, *Coal Information 2000* (Paris, France, August 2000).

[d]A.D. Ellerman, *Tradeable Permits for Greenhouse Gas Emissions: A Primer with Particular Reference to Europe* (Cambridge, MA: MIT Joint Program on the Science and Policy of Global Change, Report No. 69, November 2000).

emissions trading, but they have not put forth any specific trading proposals. The EU is also considering establishing an emissions trading program for large electric utilities and industrial sources, starting in 2005 [***9***].Under the EU program, emissions trading would be limited to carbon dioxide until 2008, with a possible expansion to include other greenhouse gases and sinks after 2008. However, the establishment of any emissions trading scheme in those countries or across the EU may be contingent upon their plans for implementing the Kyoto Protocol [***10***].

Federal and provincial governments in Canada have supported two pilot programs aimed at providing businesses and government with practical experience in emissions trading and assessing the benefits of such programs. Ontario's PERT trading program runs from 1996 to 2001, covering air pollutants (including greenhouse gases), and the GERT trading program runs from 1998 through 2001, covering greenhouse gas emission reductions from six Canadian provinces and the federal government.

The Prototype Carbon Fund

Several governments and businesses have begun to invest in carbon dioxide emission reduction projects through the World Bank's Prototype Carbon Fund, which was established in July 1999. The fund functions as a public-private partnership that aims to mobilize new and additional resources to address climate change and promote sustainable development. Contributions to the Prototype Carbon Fund from governments and businesses, which are capped at $150 million, are invested primarily in renewable energy and energy efficiency projects in developing countries and countries with economies in transition. The contributors, or "participants," receive a *pro rata* share of the emission reductions resulting from the projects, which are verified and certified in accordance with carbon purchase agreements reached with the countries "hosting" the projects.

The Prototype Carbon Fund formally started operating on April 10, 2000, and is scheduled to terminate in 2012. As of the end of September 2000, it had six participant governments and 17 participant companies, with total capitalization of $145 million.[38] In order to be compatible with the Kyoto Protocol, should it come into force, the Prototype Carbon Fund seeks to invest in projects that produce greenhouse gas emission reductions fully consistent with the emerging framework for joint implementation and clean development mechanism projects. Of the 25 projects under consideration for investment as of September 2000, 5 have already been endorsed as clean development mechanism or joint implementation projects by their host governments [***11***].

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[38]As of September 2000, the six participant governments in the Prototype Carbon Fund were Canada, Finland, the Netherlands, Norway, Sweden, and the Japan Bank for International Cooperation.

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	**99.9**	**113.1**	**115.7**	**128.8**	**138.2**	**146.9**	**155.6**	**1.4**
United States[a]	84.0	94.7	96.7	107.0	114.1	120.7	127.0	1.3
Canada	10.9	12.4	12.8	14.3	15.4	16.0	16.6	1.2
Mexico	5.0	6.0	6.1	7.5	8.7	10.1	11.9	3.2
Western Europe	**59.8**	**65.7**	**65.9**	**71.5**	**74.5**	**77.3**	**80.7**	**1.0**
United Kingdom	9.2	9.8	9.8	10.6	11.1	11.7	12.1	1.0
France	9.3	10.8	10.9	12.0	12.6	13.1	13.7	1.1
Germany	14.8	14.2	14.0	15.3	15.9	16.3	16.9	0.9
Italy	6.6	7.6	7.6	8.4	8.8	9.2	9.5	1.1
Netherlands	3.3	3.7	3.7	3.9	4.1	4.2	4.4	0.8
Other Western Europe	16.6	19.7	20.0	21.3	22.1	22.9	24.1	0.9
Industrialized Asia	**22.8**	**27.6**	**27.9**	**29.6**	**30.7**	**32.7**	**34.0**	**0.9**
Japan	17.9	21.5	21.7	22.8	23.5	25.1	26.0	0.9
Australasia	4.8	6.1	6.2	6.8	7.2	7.6	8.1	1.2
Total Industrialized	**182.4**	**206.4**	**209.6**	**229.9**	**243.4**	**256.9**	**270.4**	**1.2**
EE/FSU								
Former Soviet Union	61.0	38.8	39.3	43.2	46.4	51.8	55.8	1.7
Eastern Europe	15.3	11.9	11.3	12.7	13.9	15.3	16.5	1.8
Total EE/FSU	**76.3**	**50.7**	**50.5**	**56.0**	**60.3**	**67.2**	**72.3**	**1.7**
Developing Countries								
Developing Asia	**51.0**	**72.9**	**70.9**	**92.4**	**113.4**	**137.0**	**162.2**	**4.0**
China	27.0	35.4	32.0	43.2	55.3	69.1	84.1	4.7
India	7.8	11.6	12.2	15.5	18.4	22.2	26.1	3.7
South Korea	3.7	6.9	7.3	9.2	10.3	11.8	13.2	2.8
Other Asia	12.6	19.0	19.5	24.6	29.3	34.0	38.8	3.3
Middle East	**13.1**	**19.1**	**19.3**	**22.5**	**26.9**	**31.7**	**37.2**	**3.2**
Turkey	2.0	3.0	2.9	3.5	4.1	4.7	5.4	3.0
Other Middle East	11.1	16.1	16.4	19.0	22.9	27.0	31.8	3.2
Africa	**9.3**	**11.6**	**11.8**	**14.3**	**16.1**	**18.6**	**20.8**	**2.7**
Central and South America	**13.7**	**19.4**	**19.8**	**24.3**	**29.6**	**36.2**	**44.1**	**3.9**
Brazil	5.4	7.8	8.1	9.6	11.5	13.5	16.0	3.3
Other Central/South America	8.3	11.6	11.7	14.7	18.1	22.7	28.1	4.3
Total Developing	**87.2**	**123.0**	**121.8**	**153.5**	**186.1**	**223.4**	**264.4**	**3.8**
Total World	**346.0**	**380.0**	**381.8**	**439.3**	**489.7**	**547.4**	**607.1**	**2.2**
Annex I								
Industrialized	177.4	200.3	203.4	222.4	234.7	246.7	258.5	1.1
EE/FSU	64.8	43.7	43.6	48.0	51.5	57.5	61.9	1.7
Total Annex I	**242.2**	**244.0**	**247.0**	**270.5**	**286.1**	**304.2**	**320.3**	**1.2**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Energy totals include net imports of coal coke and electricity generated from biomass in the United States. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table A1; and World Energy Projection System (2001).

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	50.2	54.3	58.8	63.5	1.6
Natural Gas	22.7	26.2	26.8	31.2	34.4	38.5	42.0	2.2
Coal	20.5	23.5	23.5	25.9	27.0	27.6	28.2	0.9
Nuclear	7.0	8.0	8.6	9.0	8.9	8.0	7.3	-0.8
Other	9.3	10.8	11.1	12.5	13.6	14.1	14.5	1.3
Total	**99.9**	**113.1**	**115.7**	**128.8**	**138.2**	**146.9**	**155.6**	**1.4**
Western Europe								
Oil	25.8	29.1	28.7	30.4	31.0	31.4	31.8	0.5
Natural Gas	9.7	13.6	14.3	18.3	20.5	23.0	26.9	3.0
Coal	12.4	8.8	8.4	7.6	7.3	7.0	6.4	-1.3
Nuclear	7.4	8.8	8.9	8.7	8.5	8.3	7.5	-0.8
Other	4.5	5.4	5.6	6.5	7.1	7.6	8.2	1.8
Total	**59.8**	**65.7**	**65.9**	**71.5**	**74.5**	**77.3**	**80.7**	**1.0**
Industrialized Asia								
Oil	12.5	13.7	13.9	14.5	14.9	15.3	15.6	0.5
Natural Gas	2.5	3.6	3.8	4.3	4.5	4.9	5.7	2.0
Coal	4.2	5.3	5.4	5.8	5.9	6.1	6.2	0.6
Nuclear	2.0	3.2	3.2	3.3	3.5	4.3	4.3	1.5
Other	1.6	1.7	1.7	1.8	1.9	2.1	2.3	1.4
Total	**22.8**	**27.6**	**27.9**	**29.6**	**30.7**	**32.7**	**34.0**	**0.9**
Total Industrialized								
Oil	78.7	87.4	88.4	95.2	100.2	105.5	110.9	1.1
Natural Gas	35.0	43.5	44.8	53.7	59.5	66.4	74.6	2.5
Coal	37.1	37.5	37.3	39.3	40.2	40.7	40.9	0.4
Nuclear	16.3	20.0	20.6	20.9	20.9	20.5	19.1	-0.4
Other	15.4	18.0	18.3	20.8	22.6	23.7	24.9	1.5
Total	**182.4**	**206.4**	**209.6**	**229.9**	**243.4**	**256.9**	**270.4**	**1.2**
EE/FSU								
Oil	21.0	10.9	10.8	13.5	15.2	17.9	19.8	2.9
Natural Gas	28.8	22.7	22.9	25.2	28.7	34.1	38.1	2.5
Coal	20.8	11.4	11.1	10.8	9.7	8.1	7.0	-2.2
Nuclear	2.9	2.7	2.7	3.2	3.1	3.1	2.8	0.1
Other	2.8	3.0	3.0	3.2	3.5	4.0	4.5	2.1
Total	**76.3**	**50.7**	**50.5**	**56.0**	**60.3**	**67.2**	**72.3**	**1.7**
Developing Countries								
Developing Asia								
Oil	16.0	26.7	27.7	34.9	42.8	52.1	61.8	3.9
Natural Gas	3.2	6.0	6.4	10.3	13.8	18.2	23.0	6.3
Coal	27.7	34.5	30.7	38.7	46.4	54.2	62.3	3.4
Nuclear	0.9	1.5	1.6	2.3	3.0	3.6	4.6	5.0
Other	3.2	4.3	4.6	6.2	7.4	9.0	10.5	4.0
Total	**51.0**	**72.9**	**70.9**	**92.4**	**113.4**	**137.0**	**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	14.1	17.2	21.6	3.5
Natural Gas	3.9	6.9	7.1	8.7	10.6	11.9	12.9	2.9
Coal	0.8	1.2	1.1	1.2	1.4	1.4	1.4	1.1
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	1.1	1.2	4.1
Total	**13.1**	**19.1**	**19.3**	**22.5**	**26.9**	**31.7**	**37.2**	**3.2**
Africa								
Oil	4.2	5.1	5.2	6.9	8.2	9.6	11.0	3.6
Natural Gas	1.5	2.0	2.1	2.6	2.9	3.5	4.0	3.0
Coal	3.0	3.7	3.6	3.8	4.0	4.2	4.4	1.0
Nuclear	0.1	0.1	0.1	0.1	0.2	0.2	0.2	1.6
Other	0.6	0.7	0.7	0.8	0.9	1.1	1.2	2.7
Total	**9.3**	**11.6**	**11.8**	**14.3**	**16.1**	**18.6**	**20.8**	**2.7**
Central and South America								
Oil	7.0	9.4	9.5	11.0	13.3	15.9	19.2	3.4
Natural Gas	2.2	3.4	3.5	6.0	8.8	12.0	16.1	7.5
Coal	0.6	0.9	0.9	0.9	0.9	1.0	1.0	0.6
Nuclear	0.1	0.1	0.1	0.1	0.2	0.2	0.2	3.4
Other	3.9	5.6	5.7	6.2	6.6	7.0	7.6	1.4
Total	**13.7**	**19.4**	**19.8**	**24.3**	**29.6**	**36.2**	**44.1**	**3.9**
Total Developing Countries								
Oil	35.2	51.5	52.9	64.6	78.3	94.8	113.6	3.7
Natural Gas	10.8	18.3	19.2	27.6	36.0	45.7	55.9	5.2
Coal	32.1	40.3	36.3	44.7	52.7	60.8	69.2	3.1
Nuclear	1.1	1.7	1.9	2.6	3.4	4.1	5.1	4.9
Other	8.0	11.1	11.5	14.1	15.8	18.2	20.5	2.8
Total	**87.2**	**123.0**	**121.8**	**153.5**	**186.1**	**223.4**	**264.4**	**3.8**
Total World								
Oil	134.9	149.8	152.2	173.3	193.7	218.1	244.4	2.3
Natural Gas	74.5	84.5	86.9	106.5	124.2	146.2	168.6	3.2
Coal	90.0	89.3	84.8	94.8	102.6	109.6	117.1	1.5
Nuclear	20.4	24.4	25.3	26.7	27.4	27.7	27.1	0.3
Other	26.3	32.0	32.7	38.1	41.9	45.9	50.0	2.0
Total	**346.0**	**380.0**	**381.8**	**439.3**	**489.7**	**547.4**	**607.1**	**2.2**

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Energy totals include net imports of coal coke and electricity generated from biomass in the United States. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table A1; and World Energy Projection System (2001).

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**	**9,789**	**10,202**	**12,713**	**14,838**	**17,007**	**19,337**	**3.1**
United States[a]	6,836	8,706	9,074	11,299	13,156	15,033	17,029	3.0
Canada	555	662	692	841	959	1,057	1,140	2.4
Mexico	332	421	436	573	722	917	1,168	4.8
Western Europe	**7,597**	**8,721**	**8,906**	**10,405**	**11,665**	**13,005**	**14,444**	**2.3**
United Kingdom	1,146	1,345	1,372	1,637	1,851	2,116	2,380	2.7
France	1,299	1,457	1,497	1,761	1,990	2,188	2,392	2.3
Germany	1,879	2,158	2,187	2,523	2,802	3,101	3,427	2.2
Italy	1,079	1,173	1,190	1,366	1,522	1,688	1,861	2.2
Netherlands	317	391	402	470	529	592	660	2.4
Other Western Europe	1,877	2,197	2,258	2,648	2,972	3,320	3,726	2.4
Industrialized Asia	**4,054**	**4,598**	**4,644**	**5,023**	**5,462**	**6,003**	**6,542**	**1.6**
Japan	3,673	4,106	4,133	4,424	4,784	5,237	5,671	1.5
Australasia	381	491	511	600	678	766	871	2.6
Total Industrialized	**19,374**	**23,107**	**23,752**	**28,141**	**31,965**	**36,015**	**40,323**	**2.6**
EE/FSU								
Former Soviet Union	1,009	564	579	719	864	1,133	1,373	4.2
Eastern Europe	348	356	360	480	600	744	905	4.5
Total EE/FSU	**1,357**	**919**	**939**	**1,199**	**1,464**	**1,877**	**2,279**	**4.3**
Developing Countries								
Developing Asia	**1,739**	**2,944**	**3,123**	**4,468**	**6,022**	**7,946**	**10,357**	**5.9**
China	427	967	1,036	1,590	2,276	3,128	4,245	6.9
India	268	414	440	621	818	1,072	1,396	5.7
South Korea	297	449	490	649	835	1,066	1,347	4.9
Other Asia	748	1,115	1,157	1,608	2,092	2,681	3,369	5.2
Middle East	**379**	**518**	**513**	**658**	**824**	**1,045**	**1,334**	**4.7**
Turkey	140	196	186	240	301	379	478	4.6
Other Middle East	239	322	327	418	523	666	856	4.7
Africa	**405**	**466**	**474**	**617**	**759**	**915**	**1,093**	**4.1**
Central and South America	**1,136**	**1,518**	**1,498**	**1,959**	**2,445**	**3,013**	**3,696**	**4.4**
Brazil	674	830	836	1,097	1,380	1,704	2,097	4.5
Other Central/South America	462	688	662	861	1,064	1,309	1,599	4.3
Total Developing	**3,660**	**5,446**	**5,608**	**7,701**	**10,050**	**12,920**	**16,480**	**5.3**
Total World	**24,392**	**29,472**	**30,299**	**37,041**	**43,479**	**50,813**	**59,082**	**3.2**
Annex I								
Industrialized	19,043	22,686	23,316	27,569	31,242	35,099	39,155	2.5
EE/FSU	1,212	829	850	1,084	1,319	1,699	2,065	4.3
Total Annex I	**20,255**	**23,515**	**24,166**	**28,653**	**32,561**	**36,797**	**41,220**	**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.

Sources: Standard & Poor's DRI, *World Economic Outlook*, Vol. 1 (Lexington, MA, 3rd Quarter 2000); and Energy Information Administration, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table A20.

Table A4. World Oil Consumption by Region, Reference Case, 1990-2020
(Million Barrels per Day)

Region/Country	History 1990	History 1998	History 1999	Projections 2005	Projections 2010	Projections 2015	Projections 2020	Average Annual Percent Change, 1999-2020
Industrialized Countries								
North America	**20.4**	**22.7**	**23.4**	**25.6**	**27.6**	**29.9**	**32.3**	**1.5**
United States[a]	17.0	18.9	19.5	21.2	22.7	24.3	25.8	1.3
Canada	1.7	1.9	1.9	2.1	2.1	2.2	2.2	0.6
Mexico	1.7	1.9	2.0	2.3	2.8	3.4	4.2	3.7
Western Europe	**12.5**	**14.1**	**13.9**	**14.8**	**15.0**	**15.2**	**15.4**	**0.5**
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	2.2	2.2	0.4
Germany	2.7	2.9	2.8	3.0	3.1	3.1	3.1	0.4
Italy	1.9	2.1	2.0	2.1	2.2	2.2	2.2	0.5
Netherlands	0.7	0.8	0.8	0.9	0.9	0.9	0.9	0.5
Other Western Europe	3.6	4.5	4.5	4.6	4.6	4.7	4.8	0.2
Industrialized Asia	**6.2**	**6.8**	**6.9**	**7.2**	**7.3**	**7.5**	**7.7**	**0.5**
Japan	5.1	5.5	5.6	5.7	5.8	5.9	5.9	0.3
Australasia	1.0	1.3	1.3	1.4	1.5	1.7	1.8	1.5
Total Industrialized	**39.0**	**43.6**	**44.2**	**47.5**	**50.0**	**52.6**	**55.4**	**1.1**
EE/FSU								
Former Soviet Union	8.4	3.8	3.7	4.9	5.6	6.9	7.8	3.6
Eastern Europe	1.6	1.4	1.5	1.6	1.6	1.7	1.7	0.8
Total EE/FSU	**10.0**	**5.2**	**5.2**	**6.5**	**7.3**	**8.6**	**9.5**	**2.9**
Developing Countries								
Developing Asia	**7.6**	**12.8**	**13.3**	**16.8**	**20.6**	**25.0**	**29.7**	**3.9**
China	2.3	4.1	4.3	5.3	6.7	8.5	10.4	4.3
India	1.2	1.8	1.9	2.6	3.4	4.5	5.8	5.4
South Korea	1.0	2.0	2.0	2.5	2.8	3.1	3.3	2.3
Other Asia	3.1	4.9	5.0	6.3	7.6	8.9	10.2	3.5
Middle East	**3.9**	**5.0**	**5.0**	**5.7**	**6.7**	**8.3**	**10.3**	**3.5**
Turkey	0.5	0.6	0.6	0.8	1.0	1.1	1.3	3.6
Other Middle East	3.4	4.3	4.4	4.8	5.8	7.1	9.0	3.5
Africa	**2.1**	**2.5**	**2.5**	**3.4**	**4.0**	**4.6**	**5.4**	**3.6**
Central and South America	**3.4**	**4.6**	**4.7**	**5.4**	**6.5**	**7.8**	**9.4**	**3.4**
Brazil	1.3	1.9	2.0	2.3	2.9	3.6	4.5	4.1
Other Central/South America	2.1	2.7	2.7	3.0	3.5	4.1	4.8	2.8
Total Developing	**17.0**	**24.8**	**25.5**	**31.1**	**37.7**	**45.7**	**54.8**	**3.7**
Total World	**66.0**	**73.6**	**74.9**	**85.1**	**95.0**	**106.9**	**119.6**	**2.3**
Annex I								
Industrialized	37.3	41.7	42.2	45.2	47.2	49.2	51.1	0.9
EE/FSU	8.1	4.3	4.2	5.3	5.9	6.9	7.7	2.9
Total Annex I	**45.4**	**45.9**	**46.5**	**50.5**	**53.1**	**56.2**	**58.8**	**1.1**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. 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, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table A21; and World Energy Projection System (2001).

Table A5. World Natural Gas Consumption by Region, Reference Case, 1990-2020
(Trillion Cubic Feet)

Region/Country	History 1990	History 1998	History 1999	Projections 2005	Projections 2010	Projections 2015	Projections 2020	Average Annual Percent Change, 1999-2020
Industrialized Countries								
North America	**22.0**	**25.4**	**26.1**	**30.4**	**33.6**	**37.5**	**41.0**	**2.2**
United States[a]	18.7	21.3	21.7	25.2	28.0	31.6	34.7	2.3
Canada	2.4	2.9	3.1	3.5	3.7	4.0	4.3	1.5
Mexico	0.9	1.3	1.3	1.7	1.8	1.9	2.0	2.2
Western Europe	**10.1**	**13.4**	**14.0**	**17.8**	**20.0**	**22.4**	**26.1**	**3.0**
United Kingdom	2.1	3.1	3.3	3.8	4.3	4.8	5.5	2.6
France	1.0	1.3	1.3	1.8	2.2	2.5	3.2	4.2
Germany	2.7	3.0	3.0	4.1	4.5	5.0	5.9	3.2
Italy	1.7	2.2	2.4	2.8	3.1	3.4	3.6	2.0
Netherlands	1.5	1.8	1.7	1.9	2.0	2.2	2.3	1.5
Other Western Europe	1.2	2.0	2.3	3.3	3.8	4.4	5.5	4.3
Industrialized Asia	**2.6**	**3.5**	**3.6**	**4.1**	**4.3**	**4.8**	**5.4**	**2.0**
Japan	1.9	2.5	2.6	2.9	3.0	3.3	3.9	1.9
Australasia	0.8	0.9	1.0	1.1	1.3	1.4	1.5	2.3
Total Industrialized	**34.8**	**42.3**	**43.7**	**52.3**	**57.9**	**64.6**	**72.5**	**2.4**
EE/FSU								
Former Soviet Union	25.0	19.9	20.1	21.5	23.4	26.8	29.5	1.8
Eastern Europe	3.1	2.5	2.4	3.3	4.9	6.7	8.0	5.9
Total EE/FSU	**28.1**	**22.4**	**22.5**	**24.8**	**28.3**	**33.5**	**37.5**	**2.5**
Developing Countries								
Developing Asia	**3.0**	**5.6**	**6.0**	**9.6**	**12.8**	**16.8**	**21.1**	**6.2**
China	0.5	0.8	0.9	1.9	2.9	4.6	6.4	10.1
India	0.4	0.8	0.8	1.3	1.8	2.4	2.8	6.5
South Korea	0.1	0.5	0.6	0.9	1.2	1.7	2.2	6.5
Other Asia	1.9	3.6	3.8	5.5	6.9	8.2	9.6	4.5
Middle East	**3.7**	**6.6**	**6.8**	**8.3**	**10.1**	**11.3**	**12.3**	**2.9**
Turkey	0.1	0.4	0.4	0.5	0.7	0.9	1.2	4.7
Other Middle East	3.6	6.2	6.3	7.8	9.4	10.4	11.1	2.7
Africa	**1.4**	**1.8**	**2.0**	**2.4**	**2.7**	**3.3**	**3.7**	**7.5**
Central and South America	**2.0**	**3.1**	**3.2**	**5.5**	**8.1**	**11.1**	**14.8**	**7.5**
Brazil	0.1	0.2	0.2	0.7	1.2	1.5	2.0	10.8
Other Central/South America	1.9	2.9	3.0	4.9	6.9	9.6	12.7	7.1
Total Developing	**10.1**	**17.2**	**18.0**	**25.8**	**33.6**	**42.4**	**51.8**	**5.2**
Total World	**72.9**	**81.9**	**84.2**	**102.9**	**119.7**	**140.6**	**161.8**	**3.2**
Annex I								
Industrialized	33.9	41.0	42.4	50.6	56.1	62.7	70.5	2.5
EE/FSU	24.2	19.3	19.3	21.2	24.0	29.0	32.6	2.5
Total Annex I	**58.1**	**60.2**	**61.7**	**71.8**	**80.1**	**91.7**	**103.1**	**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, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table A13; and World Energy Projection System (2001).

Table A6. World Coal Consumption by Region, Reference Case, 1990-2020
(Million Short Tons)

Region/Country	History 1990	History 1998	History 1999	Projections 2005	Projections 2010	Projections 2015	Projections 2020	Average Annual Percent Change, 1999-2020
Industrialized Countries								
North America	**959**	**1,121**	**1,122**	**1,264**	**1,317**	**1,348**	**1,390**	**1.0**
United States[a]	895	1,040	1,045	1,183	1,235	1,261	1,297	1.0
Canada	55	66	63	61	61	66	69	0.4
Mexico	9	15	13	20	21	22	24	2.9
Western Europe	**894**	**566**	**546**	**492**	**479**	**463**	**431**	**-1.1**
United Kingdom	119	70	65	60	58	53	44	-1.9
France	35	29	26	20	12	12	8	-5.3
Germany	528	269	258	237	237	232	219	-0.8
Italy	23	19	19	17	18	16	16	-1.0
Netherlands	15	16	14	12	9	9	8	-2.7
Other Western Europe	173	164	165	146	145	141	136	-0.9
Industrialized Asia	**231**	**287**	**295**	**311**	**319**	**327**	**332**	**0.6**
Japan	125	144	149	163	169	176	180	0.9
Australasia	106	142	145	148	149	151	152	0.2
Total Industrialized	**2,084**	**1,974**	**1,963**	**2,067**	**2,115**	**2,139**	**2,153**	**0.4**
EE/FSU								
Former Soviet Union	848	396	414	393	371	330	297	-1.6
Eastern Europe	527	414	363	369	307	232	186	-3.1
Total EE/FSU	**1,375**	**810**	**778**	**762**	**678**	**563**	**483**	**-2.2**
Developing Countries								
Developing Asia	**1,583**	**1,903**	**1,686**	**2,127**	**2,550**	**2,975**	**3,424**	**3.4**
China	1,124	1,300	1,075	1,437	1,810	2,183	2,586	4.3
India	242	333	348	398	427	446	464	1.4
South Korea	42	60	65	71	79	86	88	1.4
Other Asia	175	210	197	220	234	259	287	1.8
Middle East	**66**	**99**	**96**	**102**	**116**	**119**	**120**	**1.1**
Turkey	60	86	84	85	95	99	101	0.9
Other Middle East	6	12	12	17	21	21	19	2.1
Africa	**152**	**181**	**177**	**188**	**194**	**207**	**216**	**1.0**
Central and South America	**26**	**42**	**41**	**41**	**42**	**44**	**46**	**0.6**
Brazil	17	28	27	28	30	31	33	1.0
Other Central/South America	9	15	14	14	12	12	13	-0.3
Total Developing	**1,827**	**2,226**	**2,000**	**2,459**	**2,901**	**3,344**	**3,807**	**3.1**
Total World	**5,287**	**5,009**	**4,740**	**5,288**	**5,694**	**6,046**	**6,443**	**1.5**
Annex I								
Industrialized	2,075	1,959	1,950	2,048	2,094	2,117	2,129	0.4
EE/FSU	1,166	702	686	668	596	489	418	-2.3
Total Annex I	**3,242**	**2,660**	**2,635**	**2,715**	**2,689**	**2,606**	**2,547**	**-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, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table A16; and World Energy Projection System (2001).

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**	**836**	**824**	**745**	**683**	**-0.8**
United States[a]	577	674	728	740	720	639	574	-1.1
Canada	69	68	70	88	95	98	100	1.7
Mexico	3	9	10	8	8	8	9	-0.5
Western Europe	**703**	**836**	**846**	**833**	**818**	**793**	**722**	**-0.8**
United Kingdom	59	95	91	68	60	52	35	-4.5
France	298	369	375	406	412	417	415	0.5
Germany	145	154	161	154	147	132	104	-2.1
Italy	0	0	0	0	0	0	0	--
Netherlands	3	4	4	4	4	0	0	-100.0
Other Western Europe	198	215	215	202	196	192	168	-1.1
Industrialized Asia	**192**	**316**	**309**	**319**	**346**	**417**	**422**	**1.5**
Japan	192	316	309	319	346	417	422	1.5
Australasia	0	0	0	0	0	0	0	--
Total Industrialized	**1,544**	**1,902**	**1,962**	**1,988**	**1,988**	**1,955**	**1,826**	**-0.3**
EE/FSU								
Former Soviet Union	201	183	190	208	211	202	177	-0.3
Eastern Europe	54	61	60	82	73	79	80	1.4
Total EE/FSU	**256**	**244**	**250**	**291**	**284**	**281**	**257**	**0.1**
Developing Countries								
Developing Asia	**88**	**145**	**160**	**225**	**293**	**349**	**444**	**11.8**
China	0	13	14	46	75	91	147	11.8
India	6	11	11	15	26	40	53	7.6
South Korea	50	85	98	125	128	153	174	2.8
Other Asia	32	36	37	39	65	65	70	3.1
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**	**13**	**15**	**17**	**18**	**1.6**
Central and South America	**9**	**10**	**11**	**15**	**16**	**21**	**23**	**3.8**
Brazil	2	3	4	8	9	17	19	8.0
Other Central/South America	7	7	7	6	6	4	4	-2.2
Total Developing	**105**	**169**	**184**	**253**	**330**	**399**	**499**	**4.9**
Total World	**1,905**	**2,315**	**2,396**	**2,532**	**2,602**	**2,636**	**2,582**	**0.4**
Annex I								
Industrialized	1,541	1,893	1,952	1,980	1,980	1,947	1,818	-0.3
EE/FSU	255	243	248	289	284	281	257	0.2
Total Annex I	**1,797**	**2,136**	**2,200**	**2,269**	**2,263**	**2,228**	**2,075**	**-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. 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, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table A8; and World Energy Projection System (2001).

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	**9.3**	**10.8**	**11.1**	**12.5**	**13.6**	**14.1**	**14.5**	**1.3**
United States[a]	5.8	7.0	7.0	7.7	8.1	8.4	8.5	1.0
Canada	3.1	3.5	3.6	4.3	4.9	5.0	5.2	1.8
Mexico	0.3	0.4	0.4	0.5	0.6	0.7	0.7	2.2
Western Europe	**4.5**	**5.4**	**5.6**	**6.5**	**7.1**	**7.6**	**8.2**	**1.8**
United Kingdom	0.1	0.1	0.1	0.2	0.2	0.3	0.3	3.7
France	0.6	0.7	0.8	0.9	1.1	1.1	1.1	1.8
Germany	0.3	0.3	0.4	0.6	0.7	0.9	1.0	4.9
Italy	0.4	0.5	0.6	0.7	0.7	0.8	0.9	1.9
Netherlands	0.0	0.0	0.0	0.1	0.1	0.1	0.2	6.5
Other Western Europe	3.2	3.7	3.7	4.1	4.2	4.4	4.7	1.2
Industrialized Asia	**1.6**	**1.7**	**1.7**	**1.8**	**1.9**	**2.1**	**2.3**	**1.4**
Japan	1.1	1.2	1.2	1.2	1.3	1.5	1.6	1.5
Australasia	0.4	0.5	0.5	0.6	0.6	0.6	0.7	1.4
Total Industrialized	**15.4**	**18.0**	**18.3**	**20.8**	**22.6**	**23.7**	**24.9**	**1.5**
EE/FSU								
Former Soviet Union	2.4	2.3	2.3	2.5	2.6	2.7	2.8	0.9
Eastern Europe	0.4	0.6	0.6	0.7	0.9	1.2	1.7	5.0
Total EE/FSU	**2.8**	**3.0**	**3.0**	**3.2**	**3.5**	**4.0**	**4.5**	**2.1**
Developing Countries								
Developing Asia	**3.2**	**4.3**	**4.6**	**6.2**	**7.4**	**9.0**	**10.5**	**4.0**
China	1.3	2.1	2.3	3.5	4.4	5.5	6.6	5.1
India	0.7	0.8	0.9	1.1	1.2	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	1.6	1.7	1.9	2.0	1.8
Middle East	**0.4**	**0.6**	**0.5**	**0.8**	**0.9**	**1.1**	**1.2**	**4.1**
Turkey	0.2	0.4	0.4	0.4	0.4	0.5	0.5	2.0
Other Middle East	0.1	0.2	0.2	0.4	0.5	0.6	0.7	6.9
Africa	**0.6**	**0.7**	**0.7**	**0.8**	**0.9**	**1.1**	**1.2**	**2.7**
Central and South America	**3.9**	**5.6**	**5.7**	**6.2**	**6.6**	**7.0**	**7.6**	**1.4**
Brazil	2.2	3.1	3.3	3.5	3.6	3.7	3.7	0.6
Other Central/South America	1.7	2.5	2.4	2.7	2.9	3.4	3.9	2.3
Total Developing	**8.0**	**11.1**	**11.5**	**14.1**	**15.8**	**18.2**	**20.5**	**2.8**
Total World	**26.3**	**32.0**	**32.7**	**38.1**	**41.9**	**45.9**	**50.0**	**2.0**
Annex I								
Industrialized	15.0	17.6	17.9	20.3	22.0	23.1	24.2	1.5
EE/FSU	2.2	2.3	2.3	2.5	2.7	3.1	3.6	2.3
Total Annex I	**17.2**	**19.9**	**20.1**	**22.8**	**24.7**	**26.2**	**27.8**	**1.6**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country. 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, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table A1; and World Energy Projection System (2001).

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**	**4,550**	**5,036**	**5,471**	**5,906**	**2.0**
United States[a]	2,817	3,400	3,236	3,761	4,147	4,484	4,804	1.9
Canada	438	485	498	567	618	656	691	1.6
Mexico	107	162	171	221	271	331	412	4.3
Western Europe	**2,077**	**2,399**	**2,435**	**2,747**	**2,955**	**3,169**	**3,425**	**1.6**
United Kingdom	287	330	333	369	393	418	442	1.4
France	326	394	399	453	490	524	567	1.7
Germany	489	492	495	567	608	647	694	1.6
Italy	222	266	272	319	352	388	425	2.1
Netherlands	72	95	98	110	118	128	137	1.6
Other Western Europe	681	822	838	929	994	1,064	1,159	1.6
Industrialized Asia	**945**	**1,158**	**1,178**	**1,284**	**1,361**	**1,472**	**1,557**	**1.3**
Japan	765	932	947	1,030	1,087	1,179	1,244	1.3
Australasia	181	226	231	254	274	293	314	1.5
Total Industrialized	**6,385**	**7,604**	**7,517**	**8,580**	**9,352**	**10,112**	**10,888**	**1.8**
EE/FSU								
Former Soviet Union	1,488	1,068	1,075	1,190	1,285	1,442	1,561	1.8
Eastern Europe	418	390	377	432	475	530	578	2.1
Total EE/FSU	**1,906**	**1,459**	**1,452**	**1,622**	**1,760**	**1,972**	**2,138**	**1.9**
Developing Countries								
Developing Asia	**1,259**	**2,175**	**2,319**	**3,088**	**3,883**	**4,815**	**5,856**	**4.5**
China	551	1,013	1,084	1,533	2,035	2,635	3,331	5.5
India	257	396	424	545	656	798	949	3.9
South Korea	93	207	233	294	333	386	437	3.0
Other Asia	357	560	578	716	858	996	1,139	3.3
Middle East	**263**	**470**	**494**	**583**	**707**	**842**	**999**	**3.4**
Turkey	51	102	106	127	150	176	205	3.2
Other Middle East	213	368	388	457	557	666	793	3.5
Africa	**287**	**361**	**367**	**472**	**566**	**690**	**796**	**3.8**
Central and South America	**449**	**656**	**684**	**844**	**1,035**	**1,268**	**1,552**	**4.0**
Brazil	229	334	354	426	521	621	747	3.6
Other Central/South America	220	322	330	418	514	647	805	4.3
Total Developing	**2,258**	**3,663**	**3,863**	**4,988**	**6,191**	**7,615**	**9,203**	**4.2**
Total World	**10,549**	**12,725**	**12,833**	**15,190**	**17,303**	**19,699**	**22,230**	**2.7**
Annex I								
Industrialized	6,278	7,442	7,346	8,359	9,082	9,781	10,477	1.7
EE/FSU	1,576	1,227	1,254	1,364	1,480	1,659	1,799	1.7
Total Annex I	**7,854**	**8,669**	**8,600**	**9,723**	**10,562**	**11,440**	**12,275**	**1.7**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Electricity consumption equals generation plus imports minus exports minus distribution losses.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table A2; and World Energy Projection System (2001).

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	**1,556**	**1,742**	**1,761**	**1,972**	**2,119**	**2,271**	**2,423**	**1.5**
United States[a]	1,345	1,495	1,511	1,690	1,809	1,928	2,041	1.4
Canada	126	146	150	158	165	173	180	0.9
Mexico	84	101	101	124	145	170	203	3.4
Western Europe	**930**	**947**	**940**	**1,005**	**1,040**	**1,076**	**1,123**	**0.9**
United Kingdom	164	154	151	168	177	184	192	1.1
France	102	110	109	116	120	126	135	1.0
Germany	271	237	230	246	252	258	267	0.7
Italy	112	122	121	131	137	141	146	0.9
Netherlands	58	66	64	66	67	69	71	0.4
Other Western Europe	223	260	264	277	287	297	313	0.8
Industrialized Asia	**357**	**412**	**422**	**447**	**461**	**479**	**497**	**0.8**
Japan	269	300	307	324	330	342	353	0.7
Australasia	88	112	115	123	130	137	144	1.1
Total Industrialized	**2,842**	**3,101**	**3,122**	**3,425**	**3,619**	**3,825**	**4,043**	**1.2**
EE/FSU								
Former Soviet Union	1,036	599	607	665	712	795	857	1.7
Eastern Europe	301	217	203	221	227	233	237	0.8
Total EE/FSU	**1,337**	**816**	**810**	**886**	**940**	**1,028**	**1,094**	**1.4**
Developing Countries								
Developing Asia	**1,053**	**1,435**	**1,361**	**1,751**	**2,137**	**2,563**	**3,013**	**3.9**
China	617	765	669	889	1,131	1,398	1,683	4.5
India	153	231	242	300	351	411	475	3.3
South Korea	61	101	107	128	144	159	175	2.4
Other Asia	223	338	343	434	511	595	679	3.3
Middle East	**231**	**325**	**330**	**378**	**451**	**531**	**627**	**3.1**
Turkey	35	50	50	57	66	75	85	2.6
Other Middle East	196	275	280	320	386	456	542	3.2
Africa	**179**	**216**	**218**	**262**	**294**	**334**	**373**	**2.6**
Central and South America	**178**	**246**	**249**	**312**	**394**	**492**	**611**	**4.4**
Brazil	62	87	88	108	139	171	212	4.3
Other Central/South America	116	159	162	204	255	321	399	4.4
Total Developing	**1,641**	**2,222**	**2,158**	**2,703**	**3,276**	**3,920**	**4,624**	**3.7**
Total World	**5,821**	**6,139**	**6,091**	**7,015**	**7,835**	**8,773**	**9,762**	**2.3**
Annex I								
Industrialized	2,758	3,001	3,022	3,301	3,475	3,656	3,841	1.1
EE/FSU	1,132	704	700	761	802	876	930	1.4
Total Annex I	**3,890**	**3,704**	**3,722**	**4,062**	**4,276**	**4,531**	**4,771**	**1.2**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. The U.S. numbers include carbon dioxide emissions attributable to renewable energy sources.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table A19; and World Energy Projection System (2001).

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**	**864**	**936**	**1,014**	**1,099**	**1.6**
United States[a]	590	635	650	702	754	807	860	1.3
Canada	61	66	68	72	75	77	77	0.6
Mexico	65	74	76	90	107	130	162	3.7
Western Europe	**474**	**525**	**517**	**548**	**559**	**566**	**572**	**0.5**
United Kingdom	66	65	63	74	76	79	81	1.2
France	67	72	72	76	78	79	79	0.4
Germany	103	107	104	112	113	113	113	0.4
Italy	74	78	74	80	82	82	83	0.5
Netherlands	27	30	31	32	33	34	35	0.5
Other Western Europe	138	172	173	175	178	179	182	0.2
Industrialized Asia	**217**	**230**	**233**	**243**	**249**	**256**	**262**	**0.6**
Japan	179	183	185	191	193	196	197	0.3
Australasia	38	46	48	52	56	60	65	1.5
Total Industrialized	**1,407**	**1,529**	**1,543**	**1,655**	**1,744**	**1,837**	**1,933**	**1.1**
EE/FSU								
Former Soviet Union	334	148	146	192	220	269	305	3.6
Eastern Europe	66	55	55	59	62	64	64	0.8
Total EE/FSU	**400**	**202**	**201**	**251**	**282**	**332**	**369**	**2.9**
Developing Countries								
Developing Asia	**304**	**479**	**496**	**626**	**767**	**934**	**1,109**	**3.9**
China	94	152	160	195	249	315	384	4.3
India	45	70	73	99	129	172	220	5.4
South Korea	38	60	62	77	85	93	100	2.3
Other Asia	127	197	201	254	303	354	404	3.4
Middle East	**155**	**195**	**198**	**222**	**264**	**324**	**406**	**3.5**
Turkey	17	22	22	29	33	39	45	3.6
Other Middle East	138	173	177	193	231	285	361	3.5
Africa	**83**	**95**	**97**	**129**	**153**	**178**	**206**	**3.6**
Central and South America	**132**	**173**	**176**	**203**	**245**	**294**	**354**	**3.4**
Brazil	51	70	71	84	106	132	165	4.1
Other Central/South America	81	104	105	119	139	162	190	2.8
Total Developing	**674**	**942**	**968**	**1,180**	**1,430**	**1,730**	**2,075**	**3.7**
Total World	**2,482**	**2,673**	**2,712**	**3,087**	**3,456**	**3,900**	**4,377**	**2.3**
Annex I								
Industrialized	1,342	1,455	1,468	1,565	1,637	1,706	1,771	0.9
EE/FSU	324	164	162	203	227	266	294	2.9
Total Annex I	**1,666**	**1,620**	**1,630**	**1,768**	**1,864**	**1,972**	**2,066**	**1.1**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table A19; and World Energy Projection System (2001).

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**	**446**	**494**	**552**	**602**	**2.3**
United States[a]	277	315	317	370	412	464	510	2.4
Canada	35	42	46	51	55	59	63	1.5
Mexico	15	20	19	25	27	29	30	2.2
Western Europe	**140**	**196**	**206**	**263**	**296**	**331**	**387**	**3.0**
United Kingdom	30	47	50	59	66	74	85	2.6
France	16	21	21	29	35	40	51	3.2
Germany	32	42	43	57	63	70	83	3.2
Italy	25	32	35	41	45	50	54	2.0
Netherlands	20	23	22	25	26	28	30	1.5
Other Western Europe	18	31	35	52	60	69	85	4.3
Industrialized Asia	**36**	**52**	**54**	**61**	**65**	**71**	**81**	**2.0**
Japan	24	38	40	44	46	50	59	1.9
Australasia	12	14	14	17	19	21	23	2.3
Total Industrialized	**503**	**626**	**641**	**771**	**854**	**954**	**1,071**	**2.5**
EE/FSU								
Former Soviet Union	369	291	294	314	342	392	432	1.8
Eastern Europe	46	36	35	48	71	99	117	5.9
Total EE/FSU	**414**	**327**	**329**	**362**	**413**	**491**	**549**	**2.5**
Developing Countries								
Developing Asia	**45**	**86**	**92**	**149**	**198**	**262**	**332**	**6.3**
China	8	13	14	31	48	76	107	10.1
India	7	13	12	22	30	39	47	6.5
South Korea	2	8	10	11	15	19	27	5.1
Other Asia	29	53	56	83	105	128	150	4.8
Middle East	**56**	**100**	**102**	**125**	**152**	**171**	**185**	**2.9**
Turkey	2	6	7	7	8	10	14	3.4
Other Middle East	54	94	96	118	144	161	171	2.8
Africa	**22**	**29**	**31**	**37**	**42**	**51**	**57**	**3.0**
Central and South America	**32**	**49**	**51**	**87**	**126**	**173**	**231**	**7.5**
Brazil	2	3	4	10	17	23	30	10.8
Other Central/South America	30	46	47	77	109	151	201	7.1
Total Developing	**155**	**263**	**276**	**397**	**518**	**658**	**805**	**5.2**
Total World	**1,072**	**1,216**	**1,247**	**1,531**	**1,785**	**2,102**	**2,425**	**3.2**
Annex I								
Industrialized	488	606	622	746	826	925	1,041	2.5
EE/FSU	344	296	277	281	283	309	350	1.1
Total Annex I	**832**	**902**	**900**	**1,027**	**1,109**	**1,234**	**1,391**	**2.1**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table A19; and World Energy Projection System (2001).

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**	**689**	**705**	**722**	**1.0**
United States[a]	485	550	549	617	643	657	671	1.0
Canada	31	38	36	35	35	38	40	0.4
Mexico	4	7	6	9	10	10	11	3.0
Western Europe	**315**	**225**	**216**	**194**	**186**	**179**	**164**	**-1.3**
United Kingdom	68	42	39	36	35	32	26	-1.9
France	20	17	15	12	7	7	5	-5.2
Germany	137	87	83	76	76	75	71	-0.8
Italy	14	11	12	10	10	9	9	-1.1
Netherlands	11	13	11	10	8	7	6	-2.8
Other Western Europe	66	56	56	50	50	48	47	-0.9
Industrialized Asia	**104**	**130**	**135**	**143**	**147**	**151**	**154**	**0.6**
Japan	66	78	81	89	92	96	98	0.9
Australasia	38	52	53	54	55	55	56	0.2
Total Industrialized	**939**	**951**	**943**	**999**	**1,021**	**1,035**	**1,039**	**0.5**
EE/FSU								
Former Soviet Union	333	160	168	159	151	134	121	-1.6
Eastern Europe	189	127	113	114	94	70	56	-3.3
Total EE/FSU	**522**	**287**	**280**	**273**	**245**	**205**	**177**	**-2.2**
Developing Countries								
Developing Asia	**704**	**870**	**773**	**977**	**1,171**	**1,367**	**1,573**	**3.4**
China	514	600	495	663	834	1,006	1,192	4.3
India	101	148	156	179	191	200	208	1.4
South Korea	21	33	36	39	44	47	48	1.4
Other Asia	67	88	87	97	103	113	125	1.8
Middle East	**20**	**30**	**29**	**31**	**35**	**36**	**36**	**1.1**
Turkey	16	23	21	22	24	25	26	0.9
Other Middle East	4	7	7	9	11	11	10	1.5
Africa	**74**	**93**	**90**	**96**	**98**	**105**	**110**	**1.0**
Central and South America	**15**	**23**	**22**	**23**	**23**	**24**	**25**	**0.6**
Brazil	9	14	13	14	15	16	17	1.1
Other Central/South America	5	9	9	9	8	8	9	-0.1
Total Developing	**812**	**1,017**	**914**	**1,126**	**1,328**	**1,532**	**1,744**	**3.1**
Total World	**2,274**	**2,254**	**2,137**	**2,397**	**2,593**	**2,771**	**2,960**	**1.6**
Annex I								
Industrialized	935	944	937	990	1,011	1,025	1,028	0.4
EE/FSU	452	259	257	250	225	187	161	-2.2
Total Annex I	**1,387**	**1,203**	**1,194**	**1,239**	**1,236**	**1,211**	**1,189**	**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.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table A19; and World Energy Projection System (2001).

Table A14. World Nuclear Generating Capacity by Region and Country, Reference Case, 1998-2020
(Megawatts)

Region/Country	History		Projections			
	1998	1999	2005	2010	2015	2020
Industrialized Countries						
North America						
United States	97,133	97,157	97,458	93,700	79,500	71,600
Canada	10,298	9,998	12,827	13,596	13,596	13,596
Mexico	1,308	1,308	1,308	1,308	1,308	1,308
Industrialized Asia						
Japan	43,691	43,691	44,489	47,619	56,634	56,637
Western Europe						
Belgium	5,712	5,712	5,712	5,712	5,712	3,966
Finland	2,656	2,656	2,656	2,656	3,656	3,656
France	61,653	63,103	64,320	64,320	64,320	63,120
Germany	22,282	21,122	20,142	18,975	16,964	13,134
Netherlands	449	449	449	449	0	0
Spain	7,350	7,470	7,470	7,317	6,871	6,871
Sweden	10,040	9,432	8,832	7,957	6,907	6,077
Switzerland	3,079	3,079	3,079	3,079	2,714	2,000
United Kingdom	12,968	12,968	11,392	9,802	8,118	5,333
Total Industrialized	**278,619**	**278,145**	**280,134**	**276,490**	**266,300**	**247,298**
EE/FSU						
Eastern Europe						
Bulgaria	3,538	3,538	2,722	1,906	1,906	1,906
Czech Republic	1,648	1,648	3,472	3,472	3,472	3,472
Hungary	1,729	1,729	1,729	1,729	1,729	1,729
Romania	650	650	650	650	1,300	1,300
Slovak Republic	2,020	2,408	2,408	1,592	1,592	1,592
Slovenia	632	632	632	632	632	632
Former Soviet Union						
Armenia	376	376	376	0	0	0
Kazakhstan	70	0	0	0	0	0
Lithuania	2,370	2,370	1,185	0	1,000	1,000
Russia	19,843	19,843	21,743	21,336	17,614	13,097
Ukraine	13,765	12,115	11,190	12,140	13,090	13,090
Total EE/FSU	**46,641**	**45,309**	**46,107**	**43,457**	**42,335**	**37,818**

See notes at end of table.

Table A14. World Nuclear Generating Capacity by Region and Country, Reference Case, 1998-2020 (Continued)
(Megawatts)

Region/Country	History 1998	History 1999	Projections 2005	Projections 2010	Projections 2015	Projections 2020
Developing Countries						
Developing Asia						
China	2,167	2,167	5,922	9,587	11,587	18,652
India	1,695	1,897	2,503	4,013	5,913	7,571
Korea, North	0	0	0	950	950	950
Korea, South	11,380	12,990	15,850	16,254	19,425	22,125
Pakistan	125	125	425	425	300	900
Taiwan	4,884	4,884	4,884	7,514	7,514	7,514
Central and South America						
Argentina	935	935	935	935	600	600
Brazil	626	626	1,855	1,855	3,084	3,084
Middle East						
Iran	0	0	1,073	1,073	2,146	2,146
Africa						
South Africa	1,842	1,842	1,842	2,062	2,172	2,282
Total Developing	23,654	25,466	35,289	44,668	53,691	65,824
Total World	**348,914**	**348,920**	**361,530**	**364,615**	**362,326**	**350,940**

Sources: **History:** International Atomic Energy Agency, *Nuclear Power Reactors in the World 1999* (Vienna, Austria, April 2000). **Projections:** Energy Information Administration (EIA), *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), 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	**2,517**	**2,850**	**2,915**	**3,245**	**3,482**	**3,702**	**3,922**	**1.4**
United States[a]	2,116	2,385	2,438	2,697	2,876	3,043	3,201	1.3
Canada	275	312	323	360	387	404	420	1.2
Mexico	126	152	155	188	219	255	301	3.2
Western Europe	**1,507**	**1,656**	**1,661**	**1,802**	**1,877**	**1,947**	**2,035**	**1.0**
United Kingdom	231	247	246	268	280	294	306	1.0
France	234	271	275	302	317	329	346	1.1
Germany	373	357	352	387	399	410	425	0.9
Italy	167	190	192	211	221	231	241	1.1
Netherlands	83	93	92	99	102	106	110	0.8
Other Western Europe	419	497	504	537	556	576	607	0.9
Industrialized Asia	**574**	**695**	**704**	**745**	**774**	**824**	**858**	**0.9**
Japan	452	541	547	575	593	632	654	0.9
Australasia	122	153	157	171	181	192	203	1.2
Total Industrialized	**4,598**	**5,201**	**5,281**	**5,793**	**6,133**	**6,473**	**6,814**	**1.2**
EE/FSU								
Former Soviet Union	1,538	978	990	1,089	1,170	1,306	1,407	1.7
Eastern Europe	386	299	284	321	349	386	416	1.8
Total EE/FSU	**1,924**	**1,277**	**1,274**	**1,410**	**1,519**	**1,692**	**1,823**	**1.7**
Developing Countries								
Developing Asia	**1,286**	**1,837**	**1,788**	**2,329**	**2,857**	**3,452**	**4,089**	**4.0**
China	680	892	805	1,089	1,395	1,740	2,120	4.7
India	196	293	307	389	464	558	657	3.7
South Korea	92	173	185	231	259	297	333	2.8
Other Asia	317	480	490	619	739	857	979	3.3
Middle East	**330**	**481**	**486**	**566**	**679**	**799**	**938**	**3.2**
Turkey	50	75	74	87	102	118	137	3.0
Other Middle East	280	405	413	479	576	681	801	3.2
Africa	**235**	**292**	**297**	**361**	**407**	**468**	**524**	**2.7**
Central and South America	**346**	**489**	**498**	**612**	**747**	**911**	**1,111**	**3.9**
Brazil	136	197	204	241	290	340	403	3.3
Other Central/South America	210	292	294	370	457	571	709	4.3
Total Developing	**2,197**	**3,099**	**3,068**	**3,868**	**4,689**	**5,630**	**6,662**	**3.8**
Total World	**8,719**	**9,577**	**9,622**	**11,071**	**12,341**	**13,795**	**15,299**	**2.2**
Annex I								
Industrialized	4,472	5,049	5,126	5,605	5,914	6,218	6,513	1.1
EE/FSU	1,632	1,100	1,098	1,211	1,297	1,448	1,559	1.7
Total Annex I	**6,104**	**6,149**	**6,224**	**6,816**	**7,211**	**7,666**	**8,072**	**1.2**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table A1; and World Energy Projection System (2001).

Table A16. World Population by Region, Reference Case, 1990-2020
(Millions)

Region/Country	History 1990	History 1998	History 1999	Projections 2005	Projections 2010	Projections 2015	Projections 2020	Annual Average Percent Change, 1999-2020
Industrialized Countries								
North America	**365**	**397**	**401**	**427**	**447**	**467**	**487**	**0.9**
United States[a]	254	271	273	288	300	313	325	0.8
Canada	28	31	31	33	34	35	37	0.8
Mexico	83	96	97	106	113	119	125	1.2
Western Europe	**377**	**387**	**388**	**390**	**389**	**387**	**385**	**0.0**
United Kingdom	58	59	59	59	59	60	60	0.1
France	57	59	59	60	61	61	62	0.2
Germany	79	82	82	82	82	82	81	-0.1
Italy	57	57	57	57	56	54	53	-0.4
Netherlands	15	16	16	16	16	16	16	0.0
Other Western Europe	112	115	115	116	115	115	114	0.0
Industrialized Asia	**148**	**153**	**153**	**156**	**157**	**156**	**158**	**0.2**
Japan	124	126	126	127	127	126	127	0.0
Australasia	24	26	27	28	29	30	32	0.8
Total Industrialized	**890**	**937**	**942**	**972**	**993**	**1,011**	**1,030**	**0.4**
EE/FSU								
Former Soviet Union	290	292	292	292	294	295	295	0.1
Eastern Europe	122	121	121	121	121	120	119	-0.1
Total EE/FSU	**412**	**413**	**413**	**413**	**414**	**415**	**414**	**0.0**
Developing Countries								
Developing Asia	**2,800**	**3,166**	**3,212**	**3,464**	**3,657**	**3,842**	**4,015**	**1.1**
China	1,155	1,255	1,266	1,326	1,373	1,418	1,454	0.7
India	851	982	998	1,087	1,152	1,212	1,272	1.2
South Korea	43	46	46	49	50	51	52	0.5
Other Asia	752	883	901	1,001	1,082	1,161	1,236	1.5
Middle East	**196**	**234**	**239**	**268**	**295**	**323**	**350**	**1.8**
Turkey	56	64	66	72	76	80	84	1.2
Other Middle East	140	170	174	197	219	243	266	2.0
Africa	**615**	**749**	**767**	**876**	**973**	**1,078**	**1,187**	**2.1**
Central and South America	**354**	**404**	**410**	**447**	**478**	**508**	**536**	**1.3**
Brazil	148	166	168	181	191	201	210	1.1
Other Central/South America	206	238	242	267	287	307	326	1.4
Total Developing	**3,965**	**4,554**	**4,628**	**5,055**	**5,403**	**5,750**	**6,088**	**1.3**
Total World	**5,266**	**5,903**	**5,983**	**6,440**	**6,811**	**7,176**	**7,532**	**1.1**
Annex I								
Industrialized	807	841	845	866	880	892	905	0.3
EE/FSU	311	308	307	303	300	297	292	-0.2
Total Annex I	**1,117**	**1,148**	**1,152**	**1,169**	**1,180**	**1,188**	**1,197**	**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.

Sources: **United States:** Energy Information Administration, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table A20. **Other Countries:** United Nations, *World Populations: The 1998 Revision, Volume 1, Comprehensive Tables* (New York, NY, 1999).

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	**99.9**	**113.1**	**115.7**	**132.4**	**144.2**	**155.5**	**168.0**	**1.8**
United States[a]	84.0	94.7	96.7	109.9	118.6	126.9	135.9	1.6
Canada	10.9	12.4	12.8	14.8	16.3	17.4	18.5	1.8
Mexico	5.0	6.0	6.1	7.8	9.4	11.2	13.7	3.9
Western Europe	**59.8**	**65.7**	**65.9**	**73.7**	**78.1**	**82.4**	**87.9**	**1.4**
United Kingdom	9.2	9.8	9.8	10.9	11.7	12.4	13.2	1.4
France	9.3	10.8	10.9	12.4	13.2	14.0	15.2	1.6
Germany	14.8	14.2	14.0	15.9	16.7	17.4	18.3	1.3
Italy	6.6	7.6	7.6	8.7	9.3	10.0	10.6	1.6
Netherlands	3.3	3.7	3.7	4.0	4.2	4.5	4.7	1.2
Other Western Europe	16.6	19.7	20.0	21.8	22.9	24.1	26.0	1.3
Industrialized Asia	**22.8**	**27.6**	**27.9**	**30.9**	**32.7**	**35.9**	**38.2**	**1.5**
Japan	17.9	21.5	21.7	23.9	25.1	27.7	29.3	1.4
Australasia	4.8	6.1	6.2	7.0	7.6	8.2	8.9	1.7
Total Industrialized	**182.4**	**206.4**	**209.6**	**237.0**	**255.0**	**273.8**	**294.2**	**1.6**
EE/FSU								
Former Soviet Union	61.0	38.8	39.3	47.7	54.2	64.2	73.1	3.0
Eastern Europe	15.3	11.9	11.3	12.5	14.4	17.0	19.4	2.6
Total EE/FSU	**76.3**	**50.7**	**50.5**	**60.2**	**68.6**	**81.2**	**92.5**	**2.9**
Developing Countries								
Developing Asia	**51.0**	**72.9**	**70.9**	**98.1**	**126.0**	**159.6**	**197.5**	**5.0**
China	27.0	35.4	32.0	45.9	61.6	80.7	103.0	5.7
India	7.8	11.6	12.2	16.4	20.4	25.8	31.8	4.7
South Korea	3.7	6.9	7.3	9.8	11.3	13.5	15.7	3.7
Other Asia	12.6	19.0	19.5	26.1	32.7	39.6	47.1	4.3
Middle East	**13.1**	**19.1**	**19.3**	**23.7**	**30.1**	**37.2**	**45.8**	**4.2**
Turkey	2.0	3.0	2.9	3.7	4.5	5.5	6.6	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**	**25.9**	**33.7**	**44.0**	**57.5**	**5.2**
Brazil	5.4	7.8	8.1	10.1	12.9	15.9	20.0	4.4
Other Central/South America	8.3	11.6	11.7	15.8	20.8	28.1	37.5	5.7
Total Developing	**87.2**	**123.0**	**121.8**	**163.0**	**207.8**	**262.7**	**326.5**	**4.8**
Total World	**346.0**	**380.0**	**381.8**	**460.2**	**531.4**	**617.7**	**713.1**	**3.0**

[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, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table B1; and World Energy Projection System (2001).

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	51.9	57.2	62.8	69.5	2.0
Natural Gas	22.7	26.2	26.8	32.2	36.0	40.8	44.2	2.4
Coal	20.5	23.5	23.5	26.5	27.9	28.8	31.0	1.3
Nuclear	7.0	8.0	8.6	9.0	8.9	8.2	7.7	-0.6
Other	9.3	10.8	11.1	12.8	14.1	14.8	15.6	1.7
Total	**99.9**	**113.1**	**115.7**	**132.4**	**144.2**	**155.5**	**168.0**	**1.8**
Western Europe								
Oil	25.8	29.1	28.7	31.4	32.5	33.5	34.6	0.9
Natural Gas	9.7	13.6	14.3	18.9	21.5	24.5	29.3	3.5
Coal	12.4	8.8	8.4	7.8	7.6	7.5	7.0	-0.9
Nuclear	7.4	8.8	8.9	8.9	8.9	8.8	8.2	-0.4
Other	4.5	5.4	5.6	6.7	7.4	8.0	8.9	2.2
Total	**59.8**	**65.7**	**65.9**	**73.7**	**78.1**	**82.4**	**87.9**	**1.4**
Industrialized Asia								
Oil	12.5	13.7	13.9	15.1	15.8	16.8	17.5	1.1
Natural Gas	2.5	3.6	3.8	4.4	4.8	5.4	6.4	2.5
Coal	4.2	5.3	5.4	6.0	6.3	6.7	6.9	1.2
Nuclear	2.0	3.2	3.2	3.4	3.8	4.7	4.9	2.1
Other	1.6	1.7	1.7	1.9	2.0	2.3	2.5	2.0
Total	**22.8**	**27.6**	**27.9**	**30.9**	**32.7**	**35.9**	**38.2**	**1.5**
Total Industrialized								
Oil	78.7	87.4	88.4	98.5	105.6	113.1	121.6	1.5
Natural Gas	35.0	43.5	44.8	55.5	62.4	70.8	79.8	2.8
Coal	37.1	37.5	37.3	40.3	41.8	43.0	45.0	0.9
Nuclear	16.3	20.0	20.6	21.4	21.6	21.7	20.7	0.0
Other	15.4	18.0	18.3	21.3	23.5	25.2	27.0	1.9
Total	**182.4**	**206.4**	**209.6**	**237.0**	**255.0**	**273.8**	**294.2**	**1.6**
EE/FSU								
Oil	21.0	10.9	10.8	14.6	17.3	21.7	25.5	4.2
Natural Gas	28.8	22.7	22.9	27.4	32.9	41.3	48.8	3.7
Coal	20.8	11.4	11.1	11.4	10.9	9.7	8.9	-1.1
Nuclear	2.9	2.7	2.7	3.4	3.5	3.7	3.6	1.3
Other	2.8	3.0	3.0	3.4	4.0	4.8	5.7	3.2
Total	**76.3**	**50.7**	**50.5**	**60.2**	**68.6**	**81.2**	**92.5**	**2.9**
Developing Countries								
Developing Asia								
Oil	16.0	26.7	27.7	37.1	47.6	60.6	75.1	4.9
Natural Gas	3.2	6.0	6.4	11.0	15.3	21.2	28.0	7.3
Coal	27.7	34.5	30.7	41.1	51.6	63.3	76.2	4.4
Nuclear	0.9	1.5	1.6	2.4	3.3	4.1	5.5	6.0
Other	3.2	4.3	4.6	6.6	8.2	10.5	12.8	5.0
Total	**51.0**	**72.9**	**70.9**	**98.1**	**126.0**	**159.6**	**197.5**	**5.0**

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	12.5	15.7	20.2	26.6	4.5
Natural Gas	3.9	6.9	7.1	9.2	11.8	14.0	15.8	3.9
Coal	0.8	1.2	1.1	1.3	1.5	1.6	1.7	2.1
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	1.3	1.5	5.1
Total	**13.1**	**19.1**	**19.3**	**23.7**	**30.1**	**37.2**	**45.8**	**4.2**
Africa								
Oil	4.2	5.1	5.2	7.4	9.1	11.2	13.6	4.7
Natural Gas	1.5	2.0	2.1	2.8	3.2	4.1	4.9	4.0
Coal	3.0	3.7	3.6	4.1	4.4	5.0	5.4	2.0
Nuclear	0.1	0.1	0.1	0.1	0.2	0.2	0.2	2.6
Other	0.6	0.7	0.7	0.9	1.0	1.3	1.5	3.7
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	11.7	15.1	19.4	25.0	4.7
Natural Gas	2.2	3.4	3.5	6.4	10.0	14.7	20.9	8.9
Coal	0.6	0.9	0.9	1.0	1.0	1.2	1.3	1.9
Nuclear	0.1	0.1	0.1	0.2	0.2	0.3	0.3	4.7
Other	3.9	5.6	5.7	6.6	7.5	8.6	9.9	2.7
Total	**13.7**	**19.4**	**19.8**	**25.9**	**33.7**	**44.0**	**57.5**	**5.2**
Total Developing Countries								
Oil	35.2	51.5	52.9	68.6	87.5	111.4	140.3	4.8
Natural Gas	10.8	18.3	19.2	29.3	40.3	54.0	69.6	6.3
Coal	32.1	40.3	36.3	47.4	58.6	71.0	84.6	4.1
Nuclear	1.1	1.7	1.9	2.7	3.7	4.7	6.2	5.9
Other	8.0	11.1	11.5	15.0	17.7	21.6	25.7	3.9
Total	**87.2**	**123.0**	**121.8**	**163.0**	**207.8**	**262.7**	**326.5**	**4.8**
Total World								
Oil	134.9	149.8	152.2	181.6	210.4	246.2	287.4	3.1
Natural Gas	74.5	84.5	86.9	112.2	135.6	166.1	198.2	4.0
Coal	90.0	89.3	84.8	99.1	111.3	123.7	138.5	2.4
Nuclear	20.4	24.4	25.3	27.5	28.9	30.2	30.5	0.9
Other	26.3	32.0	32.7	39.7	45.3	51.5	58.5	2.8
Total	**346.0**	**380.0**	**381.8**	**460.2**	**531.4**	**617.7**	**713.1**	**3.0**

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, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table B1; and World Energy Projection System (2001).

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**	**9,789**	**10,202**	**13,466**	**16,494**	**19,842**	**23,682**	**4.1**
United States[a]	6,836	8,706	9,074	11,968	14,625	17,541	20,858	4.0
Canada	555	662	692	891	1,067	1,234	1,398	3.4
Mexico	332	421	436	606	802	1,067	1,426	5.8
Western Europe	**7,597**	**8,721**	**8,906**	**11,028**	**12,980**	**15,193**	**17,717**	**3.3**
United Kingdom	1,146	1,345	1,372	1,734	2,059	2,471	2,917	3.7
France	1,299	1,457	1,497	1,867	2,214	2,556	2,934	3.3
Germany	1,879	2,158	2,187	2,675	3,119	3,624	4,205	3.2
Italy	1,079	1,173	1,190	1,448	1,694	1,972	2,283	3.2
Netherlands	317	391	402	498	588	692	809	3.4
Other Western Europe	1,877	2,197	2,258	2,806	3,306	3,878	4,569	3.4
Industrialized Asia	**4,054**	**4,598**	**4,644**	**5,328**	**6,084**	**7,021**	**8,035**	**2.6**
Japan	3,673	4,106	4,133	4,693	5,330	6,126	6,967	2.5
Australasia	381	491	511	636	754	895	1,067	3.6
Total Industrialized	**19,374**	**23,107**	**23,752**	**29,823**	**35,557**	**42,057**	**49,434**	**3.6**
EE/FSU								
Former Soviet Union	1,009	564	579	853	1,183	1,783	2,492	7.2
Eastern Europe	348	356	360	568	819	1,170	1,641	7.5
Total EE/FSU	**1,357**	**919**	**939**	**1,421**	**2,001**	**2,953**	**4,133**	**7.3**
Developing Countries								
Developing Asia	**1,739**	**2,944**	**3,123**	**4,860**	**7,027**	**9,948**	**13,914**	**7.4**
China	427	967	1,036	1,728	2,652	3,907	5,687	8.4
India	268	414	440	676	955	1,343	1,877	7.2
South Korea	297	449	490	707	977	1,337	1,815	6.4
Other Asia	748	1,115	1,157	1,750	2,444	3,362	4,535	6.7
Middle East	**379**	**518**	**513**	**717**	**964**	**1,313**	**1,799**	**6.2**
Turkey	140	196	186	261	352	476	645	6.1
Other Middle East	239	322	327	455	612	836	1,154	6.2
Africa	**405**	**466**	**474**	**672**	**888**	**1,151**	**1,476**	**5.6**
Central and South America	**1,136**	**1,518**	**1,498**	**2,133**	**2,859**	**3,786**	**4,987**	**5.9**
Brazil	674	830	836	1,195	1,614	2,141	2,829	6.0
Other Central/South America	462	688	662	938	1,245	1,645	2,158	5.8
Total Developing	**3,660**	**5,446**	**5,608**	**8,382**	**11,738**	**16,197**	**22,176**	**6.8**
Total World	**24,392**	**29,472**	**30,299**	**39,627**	**49,297**	**61,207**	**75,743**	**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: Standard & Poor's DRI, *World Economic Outlook*, Vol. 1 (Lexington, MA, 3rd Quarter 2000); Energy Information Administration (EIA), *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table B20; and EIA, World Energy Projection System (2001).

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**	**29.1**	**31.9**	**35.3**	**2.0**
United States[a]	17.0	18.9	19.5	21.9	23.8	25.7	28.0	1.7
Canada	1.7	1.9	1.9	2.1	2.3	2.4	2.5	1.1
Mexico	1.7	1.9	2.0	2.4	3.0	3.8	4.8	4.4
Western Europe	**12.5**	**14.1**	**13.9**	**15.2**	**15.8**	**16.2**	**16.7**	**0.9**
United Kingdom	1.8	1.8	1.7	2.1	2.2	2.3	2.4	1.6
France	1.8	2.0	2.0	2.2	2.3	2.4	2.4	0.9
Germany	2.7	2.9	2.8	3.2	3.2	3.3	3.3	0.8
Italy	1.9	2.1	2.0	2.2	2.3	2.4	2.4	1.0
Netherlands	0.7	0.8	0.8	0.9	0.9	1.0	1.0	0.9
Other Western Europe	3.6	4.5	4.5	4.7	4.8	5.0	5.1	0.6
Industrialized Asia	**6.2**	**6.8**	**6.9**	**7.5**	**7.8**	**8.3**	**8.7**	**1.1**
Japan	5.1	5.5	5.6	6.0	6.2	6.5	6.7	0.9
Australasia	1.0	1.3	1.3	1.5	1.6	1.8	2.0	2.0
Total Industrialized	**39.0**	**43.6**	**44.2**	**49.2**	**52.7**	**56.4**	**60.7**	**1.5**
EE/FSU								
Former Soviet Union	8.4	3.8	3.7	5.4	6.6	8.5	10.2	4.9
Eastern Europe	1.6	1.4	1.5	1.5	1.7	1.9	2.0	1.5
Total EE/FSU	**10.0**	**5.2**	**5.2**	**7.0**	**8.3**	**10.4**	**12.2**	**4.2**
Developing Countries								
Developing Asia	**7.6**	**12.8**	**13.3**	**17.8**	**22.8**	**29.1**	**36.1**	**4.9**
China	2.3	4.1	4.3	5.6	7.5	10.0	12.7	5.3
India	1.2	1.8	1.9	2.8	3.8	5.3	7.1	6.4
South Korea	1.0	2.0	2.0	2.7	3.1	3.5	3.9	3.1
Other Asia	3.1	4.9	5.0	6.7	8.5	10.4	12.4	4.4
Middle East	**3.9**	**5.0**	**5.0**	**6.0**	**7.5**	**9.7**	**12.7**	**4.5**
Turkey	0.5	0.6	0.6	0.9	1.1	1.3	1.6	4.6
Other Middle East	3.4	4.3	4.4	5.1	6.5	8.4	11.1	4.5
Africa	**2.1**	**2.5**	**2.5**	**3.6**	**4.4**	**5.4**	**6.6**	**4.7**
Central and South America	**3.4**	**4.6**	**4.7**	**5.7**	**7.4**	**9.5**	**12.2**	**4.7**
Brazil	1.3	1.9	2.0	2.4	3.3	4.3	5.7	5.2
Other Central/South America	2.1	2.7	2.7	3.3	4.1	5.2	6.5	4.3
Total Developing	**17.0**	**24.8**	**25.5**	**33.1**	**42.2**	**53.7**	**67.6**	**4.8**
Total World	**66.0**	**73.6**	**74.9**	**89.2**	**103.1**	**120.5**	**140.5**	**3.0**

[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, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table B21; and World Energy Projection System (2001).

Table B5. World Natural Gas Consumption by Region, High Economic Growth Case, 1990-2020
(Trillion Cubic Feet)

Region/Country	History 1990	1998	1999	Projections 2005	2010	2015	2020	Average Annual Percent Change, 1999-2020
Industrialized Countries								
North America	**22.0**	**25.4**	**26.1**	**31.4**	**35.1**	**39.8**	**43.1**	**2.4**
United States[a]	18.7	21.3	21.7	26.1	29.2	33.4	36.1	2.5
Canada	2.4	2.9	3.1	3.6	3.9	4.3	4.7	2.0
Mexico	0.9	1.3	1.3	1.7	2.0	2.1	2.3	2.9
Western Europe	**10.1**	**13.4**	**14.0**	**18.4**	**21.0**	**23.9**	**28.4**	**3.4**
United Kingdom	2.1	3.1	3.3	3.9	4.5	5.2	6.0	3.0
France	1.0	1.3	1.3	1.9	2.3	2.7	3.6	4.7
Germany	2.7	3.0	3.0	4.2	4.7	5.3	6.4	3.6
Italy	1.7	2.2	2.4	2.9	3.3	3.7	4.0	2.5
Netherlands	1.5	1.8	1.7	2.0	2.1	2.3	2.5	1.8
Other Western Europe	1.2	2.0	2.3	3.4	4.0	4.7	5.9	4.7
Industrialized Asia	**2.6**	**3.5**	**3.6**	**4.3**	**4.6**	**5.2**	**6.1**	**2.5**
Japan	1.9	2.5	2.6	3.1	3.2	3.7	4.4	2.4
Australasia	0.8	0.9	1.0	1.2	1.4	1.5	1.7	2.7
Total Industrialized	**34.8**	**42.3**	**43.7**	**54.0**	**60.7**	**68.9**	**77.6**	**2.8**
EE/FSU								
Former Soviet Union	25.0	19.9	20.1	23.7	27.3	33.2	38.7	3.2
Eastern Europe	3.1	2.5	2.4	3.2	5.1	7.5	9.4	6.7
Total EE/FSU	**28.1**	**22.4**	**22.5**	**27.0**	**32.4**	**40.7**	**48.0**	**3.7**
Developing Countries								
Developing Asia	**3.0**	**5.6**	**6.0**	**10.2**	**14.2**	**19.5**	**25.7**	**7.2**
China	0.5	0.8	0.9	2.0	3.2	5.3	7.8	11.1
India	0.4	0.8	0.8	1.4	2.0	2.7	3.5	7.6
South Korea	0.1	0.5	0.6	1.0	1.3	1.9	2.6	7.4
Other Asia	1.9	3.6	3.8	5.8	7.7	9.5	11.7	5.5
Middle East	**3.7**	**6.6**	**6.8**	**8.7**	**11.3**	**13.3**	**15.1**	**3.9**
Turkey	0.1	0.4	0.4	0.5	0.8	1.0	1.4	5.6
Other Middle East	3.6	6.2	6.3	8.2	10.5	12.3	13.7	3.7
Africa	**1.4**	**1.8**	**2.0**	**2.6**	**3.0**	**3.8**	**4.5**	**8.9**
Central and South America	**2.0**	**3.1**	**3.2**	**5.9**	**9.2**	**13.5**	**19.3**	**8.9**
Brazil	0.1	0.2	0.2	0.7	1.3	1.8	2.5	12.0
Other Central/South America	1.9	2.9	3.0	5.2	7.9	11.7	16.7	8.5
Total Developing	**10.1**	**17.2**	**18.0**	**27.4**	**37.6**	**50.1**	**64.5**	**6.3**
Total World	**72.9**	**81.9**	**84.2**	**108.4**	**130.7**	**159.7**	**190.2**	**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, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table B13; and World Energy Projection System (2001).

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**	**1,290**	**1,362**	**1,413**	**1,531**	**1.5**
United States[a]	895	1,040	1,045	1,206	1,274	1,318	1,426	1.5
Canada	55	66	63	63	65	71	77	0.9
Mexico	9	15	13	20	23	24	28	3.6
Western Europe	**894**	**566**	**546**	**508**	**502**	**493**	**467**	**-0.7**
United Kingdom	119	70	65	62	60	56	47	-1.5
France	35	29	26	21	13	13	9	-4.8
Germany	528	269	258	245	250	247	238	-0.4
Italy	23	19	19	18	19	17	17	-0.5
Netherlands	15	16	14	12	10	10	8	-2.4
Other Western Europe	173	164	165	150	151	149	147	-0.5
Industrialized Asia	**231**	**287**	**295**	**323**	**338**	**358**	**371**	**1.1**
Japan	125	144	149	171	181	195	203	1.5
Australasia	106	142	145	152	158	163	168	0.7
Total Industrialized	**2,084**	**1,974**	**1,963**	**2,122**	**2,202**	**2,264**	**2,369**	**0.9**
EE/FSU								
Former Soviet Union	848	396	414	435	435	411	391	-0.3
Eastern Europe	527	414	363	361	315	252	212	-2.5
Total EE/FSU	**1,375**	**810**	**778**	**795**	**751**	**663**	**603**	**-1.2**
Developing Countries								
Developing Asia	**1,583**	**1,903**	**1,686**	**2,257**	**2,836**	**3,473**	**4,183**	**4.4**
China	1,124	1,300	1,075	1,524	2,014	2,553	3,166	5.3
India	242	333	348	423	474	520	565	2.3
South Korea	42	60	65	76	87	99	104	2.3
Other Asia	175	210	197	234	261	301	348	2.7
Middle East	**66**	**99**	**96**	**108**	**129**	**140**	**148**	**2.1**
Turkey	60	86	84	90	105	115	123	1.8
Other Middle East	6	12	12	18	24	25	25	3.4
Africa	**152**	**181**	**177**	**201**	**215**	**243**	**266**	**2.0**
Central and South America	**26**	**42**	**41**	**44**	**48**	**53**	**61**	**1.9**
Brazil	17	28	27	29	34	37	42	2.1
Other Central/South America	9	15	14	15	14	16	19	1.5
Total Developing	**1,827**	**2,226**	**2,000**	**2,610**	**3,229**	**3,909**	**4,657**	**4.1**
Total World	**5,287**	**5,009**	**4,740**	**5,526**	**6,182**	**6,836**	**7,629**	**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. 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, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table B16; and World Energy Projection System (2001).

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**	**839**	**830**	**765**	**712**	**-0.6**
United States[a]	577	674	728	740	720	650	591	-1.0
Canada	69	68	70	91	101	106	111	2.2
Mexico	3	9	10	8	9	9	10	0.2
Western Europe	**703**	**836**	**846**	**858**	**858**	**847**	**789**	**-0.3**
United Kingdom	59	95	91	69	63	55	38	-4.1
France	298	369	375	419	433	447	457	0.9
Germany	145	154	161	160	154	141	112	-1.7
Italy	0	0	0	0	0	0	0	0.0
Netherlands	3	4	4	4	4	0	0	-100.0
Other Western Europe	198	215	215	206	204	203	182	-0.8
Industrialized Asia	**192**	**316**	**309**	**334**	**370**	**460**	**476**	**2.1**
Japan	192	316	309	334	370	460	476	2.1
Australasia	0	0	0	0	0	0	0	0.0
Total Industrialized	**1,544**	**1,902**	**1,962**	**2,032**	**2,058**	**2,072**	**1,978**	**0.0**
EE/FSU								
Former Soviet Union	201	183	190	230	246	250	232	0.9
Eastern Europe	54	61	60	81	76	88	94	2.2
Total EE/FSU	**256**	**244**	**250**	**311**	**321**	**338**	**326**	**1.3**
Developing Countries								
Developing Asia	**88**	**145**	**160**	**239**	**325**	**404**	**536**	**12.9**
China	0	13	14	49	83	106	180	12.9
India	6	11	11	16	28	46	65	8.6
South Korea	50	85	98	133	141	175	207	3.6
Other Asia	32	36	37	41	72	76	85	4.0
Middle East	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0.0**
Turkey	0	0	0	0	0	0	0	0.0
Other Middle East	0	0	0	0	0	0	0	0.0
Africa	**8**	**14**	**13**	**14**	**17**	**20**	**22**	**2.6**
Central and South America	**9**	**10**	**11**	**14**	**16**	**24**	**28**	**4.7**
Brazil	2	3	4	9	10	20	24	9.1
Other Central/South America	7	7	7	5	6	3	4	-2.6
Total Developing	**105**	**169**	**184**	**268**	**358**	**447**	**586**	**5.7**
Total World	**1,905**	**2,315**	**2,396**	**2,610**	**2,738**	**2,858**	**2,890**	**0.9**

[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.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table B8; and World Energy Projection System (2001).

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	**9.3**	**10.8**	**11.1**	**12.8**	**14.1**	**14.8**	**15.6**	**1.7**
United States[a]	5.8	7.0	7.0	7.8	8.3	8.6	9.0	1.2
Canada	3.1	3.5	3.6	4.5	5.1	5.5	5.8	2.3
Mexico	0.3	0.4	0.4	0.5	0.6	0.7	0.8	2.9
Western Europe	**4.5**	**5.4**	**5.6**	**6.7**	**7.4**	**8.0**	**8.9**	**2.2**
United Kingdom	0.1	0.1	0.1	0.2	0.2	0.3	0.3	4.1
France	0.6	0.7	0.8	0.9	1.1	1.2	1.2	2.3
Germany	0.3	0.3	0.4	0.6	0.8	0.9	1.1	5.4
Italy	0.4	0.5	0.6	0.7	0.7	0.9	1.0	2.4
Netherlands	0.0	0.0	0.0	0.1	0.1	0.2	0.2	6.9
Other Western Europe	3.2	3.7	3.7	4.2	4.4	4.6	5.1	1.6
Industrialized Asia	**1.6**	**1.7**	**1.7**	**1.9**	**2.0**	**2.3**	**2.5**	**2.0**
Japan	1.1	1.2	1.2	1.3	1.4	1.6	1.8	2.1
Australasia	0.4	0.5	0.5	0.6	0.6	0.7	0.7	1.9
Total Industrialized	**15.4**	**18.0**	**18.3**	**21.3**	**23.5**	**25.2**	**27.0**	**1.9**
EE/FSU								
Former Soviet Union	2.4	2.3	2.3	2.8	3.1	3.4	3.7	2.2
Eastern Europe	0.4	0.6	0.6	0.7	1.0	1.4	2.0	5.8
Total EE/FSU	**2.8**	**3.0**	**3.0**	**3.4**	**4.0**	**4.8**	**5.7**	**3.2**
Developing Countries								
Developing Asia	**3.2**	**4.3**	**4.6**	**6.6**	**8.2**	**10.5**	**12.8**	**5.0**
China	1.3	2.1	2.3	3.7	4.9	6.4	8.1	6.2
India	0.7	0.8	0.9	1.2	1.3	1.7	2.0	4.2
South Korea	0.0	0.0	0.0	0.1	0.1	0.2	0.3	8.8
Other Asia	1.1	1.3	1.4	1.7	1.9	2.2	2.4	2.7
Middle East	**0.4**	**0.6**	**0.5**	**0.8**	**1.0**	**1.3**	**1.5**	**5.1**
Turkey	0.2	0.4	0.4	0.4	0.5	0.6	0.7	3.0
Other Middle East	0.1	0.2	0.2	0.4	0.5	0.7	0.8	8.0
Africa	**0.6**	**0.7**	**0.7**	**0.9**	**1.0**	**1.3**	**1.5**	**3.7**
Central and South America	**3.9**	**5.6**	**5.7**	**6.6**	**7.5**	**8.6**	**9.9**	**2.7**
Brazil	2.2	3.1	3.3	3.7	4.1	4.3	4.7	1.7
Other Central/South America	1.7	2.5	2.4	2.9	3.4	4.2	5.3	3.8
Total Developing	**8.0**	**11.1**	**11.5**	**15.0**	**17.7**	**21.6**	**25.7**	**3.9**
Total World	**26.3**	**32.0**	**32.7**	**39.7**	**45.3**	**51.5**	**58.5**	**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. 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, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table B1; and World Energy Projection System (2001).

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**	**4,676**	**5,263**	**5,812**	**6,395**	**2.4**
United States[a]	2,817	3,400	3,236	3,845	4,299	4,715	5,135	2.2
Canada	438	485	498	598	669	726	783	2.2
Mexico	107	162	171	233	294	371	477	5.0
Western Europe	**2,077**	**2,399**	**2,435**	**2,840**	**3,109**	**3,390**	**3,741**	**2.1**
United Kingdom	287	330	333	384	417	452	486	1.8
France	326	394	399	473	522	568	632	2.2
Germany	489	492	495	590	642	692	756	2.0
Italy	222	266	272	330	373	420	469	2.6
Netherlands	72	95	98	108	119	130	142	1.8
Other Western Europe	681	822	838	955	1,037	1,128	1,256	1.9
Industrialized Asia	**945**	**1,158**	**1,178**	**1,356**	**1,467**	**1,638**	**1,771**	**2.0**
Japan	765	932	947	1,078	1,161	1,304	1,405	1.9
Australasia	181	226	231	278	306	334	366	2.2
Total Industrialized	**6,385**	**7,604**	**7,517**	**8,872**	**9,838**	**10,840**	**11,907**	**2.2**
EE/FSU								
Former Soviet Union	1,488	1,068	1,075	1,283	1,465	1,743	1,995	3.0
Eastern Europe	418	390	377	431	501	598	689	2.9
Total EE/FSU	**1,906**	**1,459**	**1,452**	**1,714**	**1,965**	**2,341**	**2,684**	**3.0**
Developing Countries								
Developing Asia	**1,259**	**2,175**	**2,319**	**3,049**	**4,005**	**5,194**	**6,587**	**5.1**
China	551	1,013	1,084	1,439	2,006	2,728	3,610	5.9
India	257	396	424	554	698	892	1,108	4.7
South Korea	93	207	233	294	344	415	487	3.6
Other Asia	357	560	578	761	957	1,159	1,381	4.2
Middle East	**263**	**470**	**494**	**578**	**741**	**927**	**1,153**	**4.1**
Turkey	51	102	106	133	166	203	248	4.2
Other Middle East	213	368	388	444	575	724	905	4.1
Africa	**287**	**361**	**367**	**504**	**629**	**810**	**979**	**4.8**
Central and South America	**449**	**656**	**684**	**878**	**1,149**	**1,506**	**1,977**	**5.2**
Brazil	229	334	354	455	589	741	945	4.8
Other Central/South America	220	322	330	423	560	765	1,032	5.6
Total Developing	**2,258**	**3,663**	**3,863**	**5,008**	**6,524**	**8,437**	**10,696**	**5.0**
Total World	**10,549**	**12,725**	**12,833**	**15,594**	**18,328**	**21,618**	**25,287**	**3.3**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Electricity consumption equals generation plus imports minus exports minus distribution losses.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table B2; and World Energy Projection System (2001).

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	**1,556**	**1,742**	**1,761**	**2,029**	**2,213**	**2,403**	**2,626**	**1.9**
United States[a]	1,345	1,495	1,511	1,737	1,883	2,028	2,193	1.8
Canada	126	146	150	163	175	188	200	1.4
Mexico	84	101	101	129	155	188	232	4.1
Western Europe	**930**	**947**	**940**	**1,038**	**1,093**	**1,149**	**1,223**	**1.3**
United Kingdom	164	154	151	173	185	196	208	1.5
France	102	110	109	120	127	135	149	1.5
Germany	271	237	230	255	266	275	290	1.1
Italy	112	122	121	137	146	154	162	1.4
Netherlands	58	66	64	68	70	74	76	0.8
Other Western Europe	223	260	264	285	299	314	339	1.2
Industrialized Asia	**357**	**412**	**422**	**466**	**490**	**526**	**558**	**1.3**
Japan	269	300	307	339	353	378	399	1.3
Australasia	88	112	115	127	137	147	159	1.5
Total Industrialized	**2,842**	**3,101**	**3,122**	**3,534**	**3,796**	**4,078**	**4,407**	**0.0**
EE/FSU								
Former Soviet Union	1,036	599	607	735	832	984	1,122	3.0
Eastern Europe	301	217	203	217	236	259	278	1.5
Total EE/FSU	**1,337**	**816**	**810**	**952**	**1,068**	**1,243**	**1,401**	**2.6**
Developing Countries								
Developing Asia	**1,053**	**1,435**	**1,361**	**1,858**	**2,375**	**2,986**	**3,669**	**4.8**
China	617	765	669	942	1,257	1,632	2,059	5.5
India	153	231	242	318	389	479	579	4.2
South Korea	61	101	107	140	163	192	219	3.4
Other Asia	223	338	343	458	566	683	813	4.2
Middle East	**231**	**325**	**330**	**399**	**505**	**624**	**773**	**4.1**
Turkey	35	50	50	62	76	91	108	3.8
Other Middle East	196	275	280	337	429	533	664	4.2
Africa	**179**	**216**	**218**	**280**	**327**	**392**	**459**	**3.6**
Central and South America	**178**	**246**	**249**	**332**	**448**	**598**	**797**	**5.7**
Brazil	62	87	88	114	155	201	265	5.4
Other Central/South America	116	159	162	219	292	397	532	5.8
Total Developing	**1,641**	**2,222**	**2,158**	**2,869**	**3,654**	**4,600**	**5,697**	**4.7**
Total World	**5,821**	**6,139**	**6,091**	**7,355**	**8,518**	**9,921**	**11,505**	**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. 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, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table B19; and World Energy Projection System (2001).

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**	**892**	**984**	**1,081**	**1,198**	**2.0**
United States[a]	590	635	650	724	789	853	927	1.7
Canada	61	66	68	74	80	83	86	1.1
Mexico	65	74	76	94	115	145	185	4.4
Western Europe	**474**	**525**	**517**	**566**	**587**	**605**	**624**	**0.9**
United Kingdom	66	65	63	76	80	84	87	1.6
France	67	72	72	78	82	84	87	0.9
Germany	103	107	104	116	119	121	123	0.8
Italy	74	78	74	84	87	90	92	1.0
Netherlands	27	30	31	33	34	36	37	0.9
Other Western Europe	138	172	173	180	186	191	197	0.6
Industrialized Asia	**217**	**230**	**233**	**253**	**265**	**282**	**294**	**1.1**
Japan	179	183	185	200	206	216	223	0.9
Australasia	38	46	48	54	59	65	72	2.0
Total Industrialized	**1,407**	**1,529**	**1,543**	**1,712**	**1,836**	**1,967**	**2,116**	**1.5**
EE/FSU								
Former Soviet Union	334	148	146	212	257	333	399	4.9
Eastern Europe	66	55	55	58	64	71	75	1.5
Total EE/FSU	**400**	**202**	**201**	**270**	**321**	**404**	**474**	**4.2**
Developing Countries								
Developing Asia	**304**	**479**	**496**	**665**	**853**	**1,087**	**1,347**	**4.9**
China	94	152	160	207	277	368	471	5.3
India	45	70	73	105	144	200	268	6.4
South Korea	38	60	62	82	94	106	119	3.1
Other Asia	127	197	201	270	338	411	489	4.3
Middle East	**155**	**195**	**198**	**235**	**296**	**381**	**500**	**4.5**
Turkey	17	22	22	30	37	45	55	4.6
Other Middle East	138	173	177	204	259	335	445	4.5
Africa	**83**	**95**	**97**	**138**	**170**	**209**	**254**	**4.7**
Central and South America	**132**	**173**	**176**	**216**	**278**	**358**	**462**	**4.7**
Brazil	51	70	71	89	119	156	206	5.2
Other Central/South America	81	104	105	128	159	202	256	4.3
Total Developing	**674**	**942**	**968**	**1,254**	**1,598**	**2,035**	**2,563**	**4.7**
Total World	**2,482**	**2,673**	**2,712**	**3,235**	**3,755**	**4,406**	**5,153**	**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, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table B19; and World Energy Projection System (2001).

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**	**516**	**585**	**634**	**2.5**
United States[a]	272	315	317	382	429	489	529	2.6
Canada	35	42	46	53	58	64	70	2.0
Mexico	15	20	19	26	30	32	35	2.9
Western Europe	**140**	**196**	**206**	**271**	**310**	**353**	**421**	**3.5**
United Kingdom	30	47	50	60	69	79	92	3.0
France	16	21	21	30	37	43	56	3.6
Germany	32	42	43	60	66	74	90	3.6
Italy	25	32	35	43	48	54	60	2.5
Netherlands	20	23	22	26	27	30	32	1.8
Other Western Europe	18	31	35	53	62	73	91	4.7
Industrialized Asia	**36**	**52**	**54**	**64**	**69**	**78**	**91**	**2.5**
Japan	24	38	40	46	49	55	66	2.4
Australasia	12	14	14	18	20	23	25	2.7
Total Industrialized	**503**	**626**	**641**	**796**	**895**	**1,017**	**1,146**	**2.8**
EE/FSU								
Former Soviet Union	369	291	294	347	399	485	565	3.2
Eastern Europe	46	36	35	47	74	110	137	6.7
Total EE/FSU	**414**	**327**	**329**	**394**	**473**	**595**	**702**	**3.7**
Developing Countries								
Developing Asia	**45**	**86**	**92**	**158**	**220**	**305**	**403**	**7.3**
China	8	13	14	33	53	89	131	11.1
India	7	13	12	24	33	46	58	7.6
South Korea	2	8	10	16	21	31	43	7.4
Other Asia	29	53	56	85	113	140	172	5.5
Middle East	**56**	**100**	**102**	**132**	**170**	**201**	**228**	**3.9**
Turkey	2	6	7	8	12	16	22	5.6
Other Middle East	54	94	96	123	158	185	206	3.7
Africa	**22**	**29**	**31**	**40**	**47**	**60**	**70**	**4.0**
Central and South America	**32**	**49**	**51**	**92**	**143**	**211**	**301**	**8.9**
Brazil	2	3	4	10	19	27	38	12.0
Other Central/South America	30	46	47	82	124	184	263	8.5
Total Developing	**155**	**263**	**276**	**422**	**581**	**777**	**1,002**	**6.3**
Total World	**1,072**	**1,216**	**1,247**	**1,612**	**1,949**	**2,388**	**2,851**	**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.
Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table B19; and World Energy Projection System (2001).

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**	**676**	**713**	**737**	**794**	**1.4**
United States[a]	485	550	549	630	665	685	737	1.4
Canada	31	38	36	36	37	41	44	0.9
Mexico	4	7	6	9	10	11	13	3.6
Western Europe	**315**	**225**	**216**	**200**	**195**	**191**	**178**	**-0.9**
United Kingdom	68	42	39	37	36	34	28	-1.5
France	20	17	15	12	7	8	5	-4.8
Germany	137	87	83	79	81	80	77	-0.4
Italy	14	11	12	11	11	11	10	-0.5
Netherlands	11	13	11	10	8	8	7	-2.4
Other Western Europe	66	56	56	51	51	51	50	-0.5
Industrialized Asia	**104**	**130**	**135**	**149**	**156**	**166**	**172**	**1.2**
Japan	66	78	81	93	98	106	111	1.5
Australasia	38	52	53	56	58	60	62	0.7
Total Industrialized	**939**	**951**	**943**	**1,026**	**1,064**	**1,094**	**1,144**	**0.9**
EE/FSU								
Former Soviet Union	333	160	168	176	176	166	158	-0.3
Eastern Europe	189	127	113	112	98	78	66	-2.5
Total EE/FSU	**522**	**287**	**280**	**288**	**274**	**245**	**224**	**-1.1**
Developing Countries								
Developing Asia	**704**	**870**	**773**	**1,035**	**1,302**	**1,594**	**1,920**	**4.4**
China	514	600	495	702	927	1,175	1,457	5.3
India	101	148	156	189	212	233	253	2.3
South Korea	21	33	36	42	48	54	57	2.3
Other Asia	67	88	87	103	115	132	152	2.7
Middle East	**20**	**30**	**29**	**32**	**39**	**42**	**44**	**2.1**
Turkey	16	23	21	23	27	29	31	1.8
Other Middle East	4	7	7	9	12	13	13	2.7
Africa	**74**	**93**	**90**	**102**	**109**	**123**	**135**	**2.0**
Central and South America	**15**	**23**	**22**	**24**	**26**	**29**	**33**	**1.9**
Brazil	9	14	13	15	17	18	21	2.1
Other Central/South America	5	9	9	9	9	10	12	1.6
Total Developing	**812**	**1,017**	**914**	**1,194**	**1,476**	**1,788**	**2,132**	**4.1**
Total World	**2,274**	**2,254**	**2,137**	**2,507**	**2,814**	**3,127**	**3,500**	**2.4**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.
Notes: EE/FSU = Eastern Europe/Former Soviet Union.
Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table B19; and World Energy Projection System (2001).

Table B14. World Nuclear Generating Capacity by Region and Country, High Economic Growth Case, 1998-2020
(Megawatts)

Region/Country	History		Projections			
	1998	1999	2005	2010	2015	2020
Industrialized Countries						
North America						
United States	97,133	97,157	97,458	96,900	94,300	88,500
Canada	10,298	9,998	13,596	13,596	13,596	13,596
Mexico	1,308	1,308	1,308	1,308	1,308	1,308
Industrialized Asia						
Japan	43,691	43,691	45,556	58,668	68,810	74,369
Western Europe						
Belgium	5,712	5,712	5,712	5,712	5,712	5,712
Finland	2,656	2,656	2,656	3,656	3,656	3,656
France	61,653	63,103	64,553	64,320	65,770	67,220
Germany	22,282	21,122	21,122	20,142	19,085	18,184
Netherlands	449	449	449	449	449	669
Spain	7,350	7,470	7,470	7,470	7,317	6,871
Sweden	10,040	9,432	9,432	8,832	7,957	6,907
Switzerland	3,079	3,079	3,079	3,079	3,079	3,299
United Kingdom	12,968	12,968	12,252	10,992	10,585	11,368
Total Industrialized	**278,619**	**278,145**	**284,643**	**295,124**	**301,624**	**301,659**
EE/FSU						
Eastern Europe						
Bulgaria	3,538	3,538	2,722	2,722	2,859	2,859
Czech Republic	1,648	1,648	3,472	3,472	3,472	3,472
Hungary	1,729	1,729	1,729	1,729	1,729	2,329
Romania	650	650	650	1,300	1,300	1,950
Slovak Republic	2,020	2,408	2,408	2,000	1,980	2,368
Slovenia	632	632	632	632	632	632
Former Soviet Union						
Armenia	376	376	376	376	376	0
Belarus	0	0	0	0	0	1,000
Kazakhstan	70	0	0	0	600	1,200
Lithuania	2,370	2,370	2,370	1,000	1,000	2,000
Russia	19,843	19,843	22,668	23,418	22,086	22,164
Ukraine	13,765	12,115	12,140	13,090	13,090	14,990
Total EE/FSU	**46,641**	**45,309**	**49,167**	**49,739**	**49,124**	**54,964**

See notes at end of table.

Table B14. World Nuclear Generating Capacity by Region and Country, High Economic Growth Case, 1998-2020 (Continued)
(Megawatts)

Region/Country	History		Projections			
	1998	1999	2005	2010	2015	2020
Developing Countries						
Developing Asia						
China	2,167	2,167	6,587	11,587	18,652	20,652
India	1,695	1,897	2,503	5,853	8,813	10,263
Indonesia	0	0	0	0	0	600
Korea, North	0	0	0	1,900	1,900	1,900
Korea, South	11,380	12,990	16,810	19,660	21,404	26,175
Malaysia	0	0	0	0	220	440
Pakistan	125	125	425	425	1,025	1,500
Philippines	0	0	0	0	0	600
Taiwan	4,884	4,884	6,199	7,514	8,514	9,514
Thailand	0	0	0	0	0	1,000
Vietnam	0	0	0	0	0	1,000
Central and South America						
Argentina	935	935	935	1,627	1,627	1,627
Brazil	626	626	1,855	3,084	4,084	4,084
Middle East						
Iran	0	0	1,073	2,146	2,586	3,026
Israel	0	0	0	0	600	600
Turkey	0	0	0	0	600	1,200
Africa						
Egypt	0	0	0	0	600	1,200
Morocco	0	0	0	0	600	600
South Africa	1,842	1,842	1,952	2,282	2,502	2,722
Total Developing	**23,654**	**25,466**	**38,339**	**56,078**	**73,727**	**88,703**
Total World	**348,914**	**348,920**	**372,149**	**400,941**	**424,475**	**445,326**

Sources: **History:** International Atomic Energy Agency, *Nuclear Power Reactors in the World 1999* (Vienna, Austria, April 2000). **Projections:** Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, based on detailed assessments of country-specific nuclear power plants.

Table B15. World Total Energy Consumption in Oil-Equivalent Units by Region, High Economic Growth Case, 1990-2020
(Million Tons Oil Equivalent)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**2,517**	**2,850**	**2,915**	**3,337**	**3,633**	**3,918**	**4,235**	**1.8**
United States[a]	2,116	2,385	2,438	2,769	2,988	3,198	3,424	1.6
Canada	275	312	323	372	410	438	466	1.8
Mexico	126	152	155	196	236	283	345	3.9
Western Europe	**1,507**	**1,656**	**1,661**	**1,858**	**1,968**	**2,076**	**2,215**	**1.4**
United Kingdom	231	247	246	275	294	313	332	1.4
France	234	271	275	312	334	353	382	1.6
Germany	373	357	352	401	421	438	461	1.3
Italy	167	190	192	219	235	251	267	1.6
Netherlands	83	93	92	101	107	112	118	1.2
Other Western Europe	419	497	504	549	577	608	655	1.3
Industrialized Asia	**574**	**695**	**704**	**777**	**825**	**906**	**964**	**1.5**
Japan	452	541	547	602	633	698	739	1.4
Australasia	122	153	157	176	192	207	225	1.7
Total Industrialized	**4,598**	**5,201**	**5,281**	**5,972**	**6,426**	**6,900**	**7,413**	**1.6**
EE/FSU								
Former Soviet Union	1,538	978	990	1,202	1,366	1,617	1,842	3.0
Eastern Europe	386	299	284	315	363	429	489	2.6
Total EE/FSU	**1,924**	**1,277**	**1,274**	**1,518**	**1,729**	**2,046**	**2,330**	**2.9**
Developing Countries								
Developing Asia	**1,286**	**1,837**	**1,788**	**2,472**	**3,176**	**4,023**	**4,978**	**5.0**
China	680	892	805	1,155	1,552	2,035	2,596	5.7
India	196	293	307	413	515	651	800	4.7
South Korea	92	173	185	246	284	340	395	3.7
Other Asia	317	480	490	657	824	997	1,187	4.3
Middle East	**330**	**481**	**486**	**598**	**759**	**939**	**1,155**	**4.2**
Turkey	50	75	74	92	114	138	167	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**	**652**	**849**	**1,109**	**1,450**	**5.2**
Brazil	136	197	204	255	325	402	504	4.4
Other Central/South America	210	292	294	397	525	707	945	5.7
Total Developing	**2,197**	**3,099**	**3,068**	**4,108**	**5,237**	**6,619**	**8,227**	**4.8**
Total World	**8,719**	**9,577**	**9,622**	**11,597**	**13,391**	**15,566**	**17,970**	**3.0**

[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, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table B1; and World Energy Projection System (2001).

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	**99.9**	**113.1**	**115.7**	**126.1**	**133.0**	**138.9**	**144.4**	**1.1**
United States[a]	84.0	94.7	96.7	105.1	110.4	115.0	119.0	1.0
Canada	10.9	12.4	12.8	13.8	14.5	14.8	15.0	0.7
Mexico	5.0	6.0	6.1	7.2	8.1	9.1	10.4	2.6
Western Europe	**59.8**	**65.7**	**65.9**	**69.4**	**71.0**	**72.4**	**74.2**	**0.6**
United Kingdom	9.2	9.8	9.8	10.3	10.6	10.9	11.2	0.7
France	9.3	10.8	10.9	11.6	12.0	12.2	12.4	0.6
Germany	14.8	14.2	14.0	14.8	15.0	15.3	15.5	0.5
Italy	6.6	7.6	7.6	8.0	8.2	8.4	8.6	0.6
Netherlands	3.3	3.7	3.7	3.8	3.9	4.0	4.1	0.5
Other Western Europe	16.6	19.7	20.0	20.8	21.2	21.7	22.3	0.5
Industrialized Asia	**22.8**	**27.6**	**27.9**	**28.3**	**28.8**	**29.7**	**30.3**	**0.4**
Japan	17.9	21.5	21.7	21.8	22.0	22.7	23.0	0.3
Australasia	4.8	6.1	6.2	6.6	6.8	7.0	7.3	0.8
Total Industrialized	**182.4**	**206.4**	**209.6**	**223.8**	**232.8**	**241.1**	**248.8**	**0.8**
EE/FSU								
Former Soviet Union	61.0	38.8	39.3	41.9	43.7	47.4	49.6	1.1
Eastern Europe	15.3	11.9	11.3	11.8	12.5	13.4	14.0	1.1
Total EE/FSU	**76.3**	**50.7**	**50.5**	**53.7**	**56.2**	**60.8**	**63.6**	**1.1**
Developing Countries								
Developing Asia	**51.0**	**72.9**	**70.9**	**84.6**	**96.7**	**108.7**	**120.2**	**2.5**
China	27.0	35.4	32.0	38.4	44.5	50.3	55.8	2.7
India	7.8	11.6	12.2	14.6	16.6	19.0	21.4	2.7
South Korea	3.7	6.9	7.3	8.6	9.3	10.3	11.1	2.0
Other Asia	12.6	19.0	19.5	23.1	26.3	29.2	32.0	2.4
Middle East	**13.1**	**19.1**	**19.3**	**21.3**	**24.0**	**26.9**	**30.2**	**2.1**
Turkey	2.0	3.0	2.9	3.3	3.6	4.0	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**	**22.8**	**26.0**	**29.6**	**33.7**	**2.6**
Brazil	5.4	7.8	8.1	9.1	10.3	11.4	12.7	2.2
Other Central/South America	8.3	11.6	11.7	13.7	15.8	18.2	21.0	2.8
Total Developing	**87.2**	**123.0**	**121.8**	**142.1**	**161.3**	**181.1**	**200.9**	**2.4**
Total World	**346.0**	**380.0**	**381.8**	**419.6**	**450.4**	**482.9**	**513.4**	**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. 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, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table B1; and World Energy Projection System (2001).

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	48.9	52.0	55.1	58.1	1.1
Natural Gas	22.7	26.2	26.8	30.4	33.1	36.2	38.8	1.8
Coal	20.5	23.5	23.5	25.7	26.2	26.7	27.0	0.7
Nuclear	7.0	8.0	8.6	8.9	8.8	7.8	7.0	-1.0
Other	9.3	10.8	11.1	12.3	13.0	13.2	13.5	0.9
Total	**99.9**	**113.1**	**115.7**	**126.1**	**133.0**	**138.9**	**144.4**	**1.1**
Western Europe								
Oil	25.8	29.1	28.7	29.5	29.6	29.5	29.2	0.1
Natural Gas	9.7	13.6	14.3	17.7	19.6	21.5	24.7	2.6
Coal	12.4	8.8	8.4	7.4	6.9	6.6	5.9	-1.7
Nuclear	7.4	8.8	8.9	8.4	8.1	7.7	6.8	-1.2
Other	4.5	5.4	5.6	6.3	6.8	7.1	7.5	1.4
Total	**59.8**	**65.7**	**65.9**	**69.4**	**71.0**	**72.4**	**74.2**	**0.6**
Industrialized Asia								
Oil	12.5	13.7	13.9	13.9	13.9	13.9	13.9	0.0
Natural Gas	2.5	3.6	3.8	4.1	4.2	4.5	5.0	1.4
Coal	4.2	5.3	5.4	5.5	5.6	5.6	5.5	0.1
Nuclear	2.0	3.2	3.2	3.1	3.3	3.8	3.8	0.9
Other	1.6	1.7	1.7	1.7	1.8	1.9	2.0	0.9
Total	**22.8**	**27.6**	**27.9**	**28.3**	**28.8**	**29.7**	**30.3**	**0.4**
Total Industrialized								
Oil	78.7	87.4	88.4	92.3	95.5	98.4	101.2	0.6
Natural Gas	35.0	43.5	44.8	52.2	56.8	62.2	68.5	2.0
Coal	37.1	37.5	37.3	38.6	38.7	38.8	38.5	0.1
Nuclear	16.3	20.0	20.6	20.5	20.2	19.4	17.7	-0.7
Other	15.4	18.0	18.3	20.3	21.6	22.3	23.0	1.1
Total	**182.4**	**206.4**	**209.6**	**223.8**	**232.8**	**241.1**	**248.8**	**0.8**
EE/FSU								
Oil	21.0	10.9	10.8	13.0	14.2	16.2	17.5	2.3
Natural Gas	28.8	22.7	22.9	24.3	26.8	30.9	33.5	1.8
Coal	20.8	11.4	11.1	10.3	9.0	7.3	6.1	-2.8
Nuclear	2.9	2.7	2.7	3.1	2.9	2.8	2.5	-0.5
Other	2.8	3.0	3.0	3.1	3.3	3.6	4.0	1.4
Total	**76.3**	**50.7**	**50.5**	**53.7**	**56.2**	**60.8**	**63.6**	**1.1**
Developing Countries								
Developing Asia								
Oil	16.0	26.7	27.7	32.3	37.2	42.5	47.5	2.6
Natural Gas	3.2	6.0	6.4	9.6	12.0	15.0	17.8	5.0
Coal	27.7	34.5	30.7	35.0	38.6	41.3	43.8	1.7
Nuclear	0.9	1.5	1.6	2.1	2.6	3.0	3.5	3.8
Other	3.2	4.3	4.6	5.6	6.2	7.0	7.6	2.4
Total	**51.0**	**72.9**	**70.9**	**84.6**	**96.7**	**108.7**	**120.2**	**2.5**

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	11.2	12.6	14.6	17.5	2.4
Natural Gas	3.9	6.9	7.1	8.2	9.4	10.1	10.4	1.8
Coal	0.8	1.2	1.1	1.1	1.2	1.2	1.1	0.1
Nuclear	0.0	0.0	0.0	0.0	0.0	0.1	0.1	--
Other	0.4	0.6	0.5	0.8	0.8	0.9	1.0	3.1
Total	**13.1**	**19.1**	**19.3**	**21.3**	**24.0**	**26.9**	**30.2**	**2.1**
Africa								
Oil	4.2	5.1	5.2	6.5	7.4	8.1	9.0	2.6
Natural Gas	1.5	2.0	2.1	2.4	2.6	3.0	3.2	2.0
Coal	3.0	3.7	3.6	3.6	3.6	3.6	3.6	0.0
Nuclear	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.6
Other	0.6	0.7	0.7	0.8	0.8	0.9	1.0	1.7
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	10.3	11.6	13.1	14.7	2.1
Natural Gas	2.2	3.4	3.5	5.6	7.7	9.9	12.3	6.1
Coal	0.6	0.9	0.9	0.8	0.8	0.8	0.8	-0.7
Nuclear	0.1	0.1	0.1	0.1	0.1	0.2	0.2	2.1
Other	3.9	5.6	5.7	5.8	5.8	5.8	5.8	0.1
Total	**13.7**	**19.4**	**19.8**	**22.8**	**26.0**	**29.6**	**33.7**	**2.6**
Total Developing Countries								
Oil	35.2	51.5	52.9	60.2	68.7	78.3	88.6	2.5
Natural Gas	10.8	18.3	19.2	25.9	31.8	37.9	43.7	4.0
Coal	32.1	40.3	36.3	40.6	44.2	46.9	49.3	1.5
Nuclear	1.1	1.7	1.9	2.4	3.0	3.4	4.0	3.7
Other	8.0	11.1	11.5	13.0	13.6	14.6	15.4	1.4
Total	**87.2**	**123.0**	**121.8**	**142.1**	**161.3**	**181.1**	**200.9**	**2.4**
Total World								
Oil	134.9	149.8	152.2	165.5	178.4	192.9	207.3	1.5
Natural Gas	74.5	84.5	86.9	102.3	115.5	131.0	145.7	2.5
Coal	90.0	89.3	84.8	89.5	91.9	93.0	93.9	0.5
Nuclear	20.4	24.4	25.3	25.9	26.1	25.6	24.1	-0.2
Other	26.3	32.0	32.7	36.4	38.5	40.4	42.3	1.2
Total	**346.0**	**380.0**	**381.8**	**419.6**	**450.4**	**482.9**	**513.4**	**1.4**

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Energy totals include net imports of coal coke and electricity generated from biomass in the United States. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table B1; and World Energy Projection System (2001).

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**	**9,789**	**10,202**	**12,002**	**13,342**	**14,563**	**15,768**	**2.1**
United States[a]	6,836	8,706	9,074	10,668	11,831	12,873	13,885	2.0
Canada	555	662	692	794	862	904	928	1.4
Mexico	332	421	436	541	650	786	955	3.8
Western Europe	**7,597**	**8,721**	**8,906**	**9,811**	**10,472**	**11,116**	**11,753**	**1.3**
United Kingdom	1,146	1,345	1,372	1,544	1,662	1,810	1,938	1.7
France	1,299	1,457	1,497	1,661	1,786	1,870	1,946	1.3
Germany	1,879	2,158	2,187	2,379	2,515	2,650	2,787	1.2
Italy	1,079	1,173	1,190	1,288	1,366	1,442	1,514	1.2
Netherlands	317	391	402	443	475	506	537	1.4
Other Western Europe	1,877	2,197	2,258	2,497	2,668	2,838	3,032	1.4
Industrialized Asia	**4,054**	**4,598**	**4,644**	**4,733**	**4,898**	**5,125**	**5,316**	**0.6**
Japan	3,673	4,106	4,133	4,167	4,290	4,470	4,607	0.5
Australasia	381	491	511	566	608	655	709	1.6
Total Industrialized	**19,374**	**23,107**	**23,752**	**26,547**	**28,713**	**30,803**	**32,836**	**1.6**
EE/FSU								
Former Soviet Union	1,009	564	579	659	736	898	1,013	2.7
Eastern Europe	348	356	360	440	512	591	668	3.0
Total EE/FSU	**1,357**	**919**	**939**	**1,099**	**1,248**	**1,489**	**1,681**	**2.8**
Developing Countries								
Developing Asia	**1,739**	**2,944**	**3,123**	**3,982**	**4,867**	**5,816**	**6,857**	**3.8**
China	427	967	1,036	1,341	1,667	1,986	2,336	3.9
India	268	414	440	571	699	853	1,034	4.2
South Korea	297	449	490	595	713	846	996	3.4
Other Asia	748	1,115	1,157	1,476	1,788	2,132	2,492	3.7
Middle East	**379**	**518**	**513**	**603**	**702**	**829**	**985**	**3.2**
Turkey	140	196	186	220	257	301	353	3.1
Other Middle East	239	322	327	383	446	528	632	3.2
Africa	**405**	**466**	**474**	**566**	**648**	**726**	**806**	**2.6**
Central and South America	**1,136**	**1,518**	**1,498**	**1,796**	**2,085**	**2,391**	**2,727**	**2.9**
Brazil	674	830	836	1,006	1,178	1,353	1,548	3.0
Other Central/South America	462	688	662	790	908	1,038	1,180	2.8
Total Developing	**3,660**	**5,446**	**5,608**	**6,947**	**8,302**	**9,763**	**11,375**	**3.4**
Total World	**24,392**	**29,472**	**30,299**	**34,593**	**38,263**	**42,055**	**45,892**	**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: Standard & Poor's DRI, *World Economic Outlook*, Vol. 1 (Lexington, MA, 3rd Quarter 2000); Energy Information Administration (EIA), *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table B20; and EIA, World Energy Projection System (2001).

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**	**24.9**	**26.5**	**28.0**	**29.5**	**1.1**
United States[a]	17.0	18.9	19.5	20.7	21.8	22.9	23.9	1.0
Canada	1.7	1.9	1.9	2.0	2.0	2.0	2.0	0.1
Mexico	1.7	1.9	2.0	2.3	2.6	3.1	3.7	3.0
Western Europe	**12.5**	**14.1**	**13.9**	**14.3**	**14.3**	**14.3**	**14.1**	**0.1**
United Kingdom	1.8	1.8	1.7	2.0	2.0	2.0	2.0	0.8
France	1.8	2.0	2.0	2.1	2.1	2.1	2.0	0.0
Germany	2.7	2.9	2.8	2.9	2.9	2.9	2.8	0.0
Italy	1.9	2.1	2.0	2.0	2.0	2.0	2.0	0.0
Netherlands	0.7	0.8	0.8	0.8	0.8	0.9	0.9	0.2
Other Western Europe	3.6	4.5	4.5	4.5	4.5	4.4	4.4	-0.1
Industrialized Asia	**6.2**	**6.8**	**6.9**	**6.9**	**6.9**	**6.9**	**6.9**	**0.0**
Japan	5.1	5.5	5.6	5.5	5.4	5.3	5.2	-0.3
Australasia	1.0	1.3	1.3	1.4	1.5	1.5	1.6	1.0
Total Industrialized	**39.0**	**43.6**	**44.2**	**46.1**	**47.7**	**49.1**	**50.5**	**0.6**
EE/FSU								
Former Soviet Union	8.4	3.8	3.7	4.7	5.3	6.3	6.9	3.0
Eastern Europe	1.6	1.4	1.5	1.5	1.5	1.5	1.4	0.0
Total EE/FSU	**10.0**	**5.2**	**5.2**	**6.2**	**6.8**	**7.8**	**8.4**	**2.3**
Developing Countries								
Developing Asia	**7.6**	**12.8**	**13.3**	**15.5**	**17.8**	**20.4**	**22.8**	**2.6**
China	2.3	4.1	4.3	4.7	5.4	6.2	6.9	2.3
India	1.2	1.8	1.9	2.5	3.1	3.9	4.7	4.4
South Korea	1.0	2.0	2.0	2.4	2.5	2.7	2.8	1.5
Other Asia	3.1	4.9	5.0	6.0	6.8	7.7	8.4	2.5
Middle East	**3.9**	**5.0**	**5.0**	**5.4**	**6.0**	**7.0**	**8.4**	**2.4**
Turkey	0.5	0.6	0.6	0.8	0.9	1.0	1.1	2.6
Other Middle East	3.4	4.3	4.4	4.6	5.2	6.1	7.3	2.4
Africa	**2.1**	**2.5**	**2.5**	**3.1**	**3.6**	**3.9**	**4.3**	**2.6**
Central and South America	**3.4**	**4.6**	**4.7**	**5.0**	**5.7**	**6.4**	**7.1**	**2.1**
Brazil	1.3	1.9	2.0	2.2	2.6	3.1	3.6	3.0
Other Central/South America	2.1	2.7	2.7	2.8	3.1	3.3	3.5	1.3
Total Developing	**17.0**	**24.8**	**25.5**	**29.0**	**33.1**	**37.7**	**42.7**	**2.5**
Total World	**66.0**	**73.6**	**74.9**	**81.3**	**87.6**	**94.6**	**101.6**	**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, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table B21; and World Energy Projection System (2001).

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**	**29.6**	**32.2**	**35.3**	**37.8**	**1.8**
United States[a]	18.7	21.3	21.7	24.7	27.0	29.9	32.2	1.9
Canada	2.4	2.9	3.1	3.3	3.5	3.7	3.8	1.0
Mexico	0.9	1.3	1.3	1.6	1.7	1.7	1.7	1.6
Western Europe	**10.1**	**13.4**	**14.0**	**17.3**	**19.0**	**20.9**	**24.0**	**2.6**
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	2.1	2.4	2.9	3.8
Germany	2.7	3.0	3.0	3.9	4.2	4.6	5.4	2.8
Italy	1.7	2.2	2.4	2.7	2.9	3.1	3.3	1.5
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	3.3	3.7	4.2	5.1	3.9
Industrialized Asia	**2.6**	**3.5**	**3.6**	**3.9**	**4.1**	**4.3**	**4.8**	**1.4**
Japan	1.9	2.5	2.6	2.8	2.8	3.0	3.4	1.3
Australasia	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.8
Total Industrialized	**34.8**	**42.3**	**43.7**	**50.8**	**55.3**	**60.5**	**66.6**	**2.0**
EE/FSU								
Former Soviet Union	25.0	19.9	20.1	20.8	22.0	24.5	26.3	1.3
Eastern Europe	3.1	2.5	2.4	3.0	4.4	5.9	6.8	5.1
Total EE/FSU	**28.1**	**22.4**	**22.5**	**23.9**	**26.4**	**30.4**	**33.0**	**1.8**
Developing Countries								
Developing Asia	**3.0**	**5.6**	**6.0**	**8.9**	**11.2**	**13.8**	**16.4**	**4.9**
China	0.5	0.8	0.9	1.7	2.3	3.3	4.2	7.9
India	0.4	0.8	0.8	1.3	1.6	2.0	2.3	5.5
South Korea	0.1	0.5	0.6	0.9	1.1	1.5	1.9	5.6
Other Asia	1.9	3.6	3.8	5.1	6.2	7.0	7.9	3.6
Middle East	**3.7**	**6.6**	**6.8**	**7.8**	**9.0**	**9.6**	**9.9**	**1.8**
Turkey	0.1	0.4	0.4	0.5	0.6	0.8	0.9	3.7
Other Middle East	3.6	6.2	6.3	7.3	8.4	8.9	9.0	2.0
Africa	**1.4**	**1.8**	**2.0**	**2.2**	**2.4**	**2.8**	**3.0**	**2.0**
Central and South America	**2.0**	**3.1**	**3.2**	**5.2**	**7.1**	**9.1**	**11.3**	**6.1**
Brazil	0.1	0.2	0.2	0.6	1.0	1.3	1.6	9.6
Other Central/South America	1.9	2.9	3.0	4.6	6.0	7.8	9.7	5.7
Total Developing	**10.1**	**17.2**	**18.0**	**24.2**	**29.7**	**35.3**	**40.6**	**3.9**
Total World	**72.9**	**81.9**	**84.2**	**98.9**	**111.4**	**126.2**	**140.2**	**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, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table B13; and World Energy Projection System (2001).

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**	**1,253**	**1,280**	**1,306**	**1,328**	**0.8**
United States[a]	895	1,040	1,045	1,174	1,202	1,226	1,245	0.8
Canada	55	66	63	60	58	61	62	-0.1
Mexico	9	15	13	19	20	20	21	2.3
Western Europe	**894**	**566**	**546**	**477**	**457**	**435**	**397**	**-1.5**
United Kingdom	119	70	65	58	55	49	40	-2.2
France	35	29	26	19	11	12	8	-5.7
Germany	528	269	258	228	225	217	202	-1.2
Italy	23	19	19	17	16	15	14	-1.5
Netherlands	15	16	14	12	9	9	7	-3.1
Other Western Europe	173	164	165	143	140	134	126	-1.3
Industrialized Asia	**231**	**287**	**295**	**299**	**300**	**299**	**297**	**0.0**
Japan	125	144	149	156	158	159	159	0.3
Australasia	106	142	145	143	141	140	138	-0.2
Total Industrialized	**2,084**	**1,974**	**1,963**	**2,029**	**2,037**	**2,040**	**2,022**	**0.1**
EE/FSU								
Former Soviet Union	848	396	414	381	351	304	265	-2.1
Eastern Europe	527	414	363	341	274	198	153	-4.0
Total EE/FSU	**1,375**	**810**	**778**	**722**	**625**	**502**	**419**	**-2.9**
Developing Countries								
Developing Asia	**1,583**	**1,903**	**1,686**	**1,925**	**2,122**	**2,269**	**2,405**	**1.7**
China	1,124	1,300	1,075	1,276	1,456	1,589	1,715	2.2
India	242	333	348	375	384	382	380	0.4
South Korea	42	60	65	67	72	75	74	0.6
Other Asia	175	210	197	207	210	222	236	0.9
Middle East	**66**	**99**	**96**	**97**	**103**	**101**	**97**	**0.1**
Turkey	60	86	84	80	85	84	83	-0.1
Other Middle East	6	12	12	16	18	17	15	0.8
Africa	**152**	**181**	**177**	**176**	**174**	**176**	**175**	**0.0**
Central and South America	**26**	**42**	**41**	**39**	**37**	**36**	**35**	**-0.7**
Brazil	17	28	27	26	27	27	27	-0.1
Other Central/South America	9	15	14	12	10	9	9	-2.1
Total Developing	**1,827**	**2,226**	**2,000**	**2,237**	**2,436**	**2,582**	**2,713**	**1.5**
Total World	**5,287**	**5,009**	**4,740**	**4,988**	**5,098**	**5,124**	**5,154**	**0.4**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country. To convert short tons to metric tons, divide each number in the table by 1.102.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table B16; and World Energy Projection System (2001).

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**	**833**	**818**	**729**	**651**	**-1.0**
United States[a]	577	674	728	740	720	632	554	-1.3
Canada	69	68	70	85	90	90	90	1.2
Mexico	3	9	10	8	8	8	7	-1.1
Western Europe	**703**	**836**	**846**	**808**	**780**	**743**	**659**	**-1.2**
United Kingdom	59	95	91	66	57	48	32	-4.8
France	298	369	375	394	391	389	376	0.0
Germany	145	154	161	148	139	124	95	-2.5
Italy	0	0	0	0	0	0	0	0.0
Netherlands	3	4	4	4	3	0	0	-100.0
Other Western Europe	198	215	215	197	189	182	156	-1.5
Industrialized Asia	**192**	**316**	**309**	**305**	**324**	**377**	**373**	**0.9**
Japan	192	316	309	305	324	377	373	0.9
Australasia	0	0	0	0	0	0	0	0.0
Total Industrialized	**1,544**	**1,902**	**1,962**	**1,946**	**1,922**	**1,849**	**1,684**	**-0.7**
EE/FSU								
Former Soviet Union	201	183	190	202	198	185	157	-0.9
Eastern Europe	54	61	60	76	66	69	68	0.6
Total EE/FSU	**256**	**244**	**250**	**278**	**264**	**254**	**226**	**-0.5**
Developing Countries								
Developing Asia	**88**	**145**	**160**	**209**	**258**	**290**	**345**	**3.7**
China	0	13	14	41	60	66	98	9.6
India	6	11	11	14	23	34	43	6.6
South Korea	50	85	98	117	116	134	147	1.9
Other Asia	32	36	37	36	58	56	57	2.1
Middle East	**0**	**0**	**0**	**0**	**5**	**10**	**11**	**0.0**
Turkey	0	0	0	0	0	0	0	0.0
Other Middle East	0	0	0	0	5	10	11	0.0
Africa	**8**	**14**	**13**	**13**	**14**	**14**	**15**	**0.6**
Central and South America	**9**	**10**	**11**	**12**	**13**	**16**	**16**	**2.1**
Brazil	2	3	4	8	8	15	15	6.8
Other Central/South America	7	7	7	5	4	1	1	-8.3
Total Developing	**105**	**169**	**184**	**234**	**289**	**330**	**387**	**3.6**
Total World	**1,905**	**2,315**	**2,396**	**2,458**	**2,475**	**2,433**	**2,296**	**-0.2**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table B8; and World Energy Projection System (2001).

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	**9.3**	**10.8**	**11.1**	**12.3**	**13.0**	**13.2**	**13.5**	**0.9**
United States[a]	5.8	7.0	7.0	7.6	7.9	8.0	8.1	0.7
Canada	3.1	3.5	3.6	4.2	4.6	4.6	4.7	1.3
Mexico	0.3	0.4	0.4	0.5	0.6	0.6	0.6	1.6
Western Europe	**4.5**	**5.4**	**5.6**	**6.3**	**6.8**	**7.1**	**7.5**	**1.4**
United Kingdom	0.1	0.1	0.1	0.2	0.2	0.2	0.3	3.3
France	0.6	0.7	0.8	0.9	1.0	1.0	1.0	1.4
Germany	0.3	0.3	0.4	0.6	0.7	0.8	0.9	4.5
Italy	0.4	0.5	0.6	0.6	0.7	0.7	0.8	1.4
Netherlands	0.0	0.0	0.0	0.1	0.1	0.1	0.2	6.1
Other Western Europe	3.2	3.7	3.7	4.0	4.1	4.2	4.4	0.8
Industrialized Asia	**1.6**	**1.7**	**1.7**	**1.7**	**1.8**	**1.9**	**2.0**	**0.9**
Japan	1.1	1.2	1.2	1.2	1.2	1.3	1.4	0.9
Australasia	0.4	0.5	0.5	0.5	0.6	0.6	0.6	0.9
Total Industrialized	**15.4**	**18.0**	**18.3**	**20.3**	**21.6**	**22.3**	**23.0**	**1.1**
EE/FSU								
Former Soviet Union	2.4	2.3	2.3	2.5	2.5	2.5	2.5	0.3
Eastern Europe	0.4	0.6	0.6	0.6	0.8	1.1	1.5	4.2
Total EE/FSU	**2.8**	**3.0**	**3.0**	**3.1**	**3.3**	**3.6**	**4.0**	**1.4**
Developing Countries								
Developing Asia	**3.2**	**4.3**	**4.6**	**5.6**	**6.2**	**7.0**	**7.6**	**2.4**
China	1.3	2.1	2.3	3.1	3.5	4.0	4.4	3.1
India	0.7	0.8	0.9	1.0	1.1	1.2	1.4	2.3
South Korea	0.0	0.0	0.0	0.1	0.1	0.1	0.2	7.0
Other Asia	1.1	1.3	1.4	1.5	1.5	1.6	1.6	0.8
Middle East	**0.4**	**0.6**	**0.5**	**0.8**	**0.8**	**0.9**	**1.0**	**3.1**
Turkey	0.2	0.4	0.4	0.4	0.4	0.4	0.5	1.1
Other Middle East	0.1	0.2	0.2	0.4	0.4	0.5	0.5	5.8
Africa	**0.6**	**0.7**	**0.7**	**0.8**	**0.8**	**0.9**	**1.0**	**1.7**
Central and South America	**3.9**	**5.6**	**5.7**	**5.8**	**5.8**	**5.8**	**5.8**	**0.1**
Brazil	2.2	3.1	3.3	3.3	3.2	3.1	3.0	-0.5
Other Central/South America	1.7	2.5	2.4	2.5	2.5	2.7	2.8	0.8
Total Developing	**8.0**	**11.1**	**11.5**	**13.0**	**13.6**	**14.6**	**15.4**	**1.4**
Total World	**26.3**	**32.0**	**32.7**	**36.4**	**38.5**	**40.4**	**42.3**	**1.2**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country. U.S. totals include net electricity imports, methanol, and liquid hydrogen.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table B1; and World Energy Projection System (2001).

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**	**4,475**	**4,869**	**5,204**	**5,513**	**1.7**
United States[a]	2,817	3,400	3,236	3,700	4,020	4,286	4,516	1.6
Canada	438	485	498	561	595	617	634	1.2
Mexico	107	162	171	214	254	302	363	3.7
Western Europe	**2,077**	**2,399**	**2,435**	**2,675**	**2,829**	**2,983**	**3,157**	**1.2**
United Kingdom	287	330	333	364	380	398	414	1.0
France	326	394	399	444	471	494	520	1.3
Germany	489	492	495	548	578	608	641	1.2
Italy	222	266	272	305	329	355	381	1.6
Netherlands	72	95	98	103	109	116	123	1.1
Other Western Europe	681	822	838	911	961	1,013	1,078	1.2
Industrialized Asia	**945**	**1,158**	**1,178**	**1,244**	**1,292**	**1,353**	**1,400**	**0.8**
Japan	765	932	947	983	1,018	1,066	1,100	0.7
Australasia	181	226	231	261	274	286	300	1.3
Total Industrialized	**6,385**	**7,604**	**7,517**	**8,394**	**8,989**	**9,540**	**10,069**	**1.4**
EE/FSU								
Former Soviet Union	1,488	1,068	1,075	1,126	1,181	1,287	1,355	1.1
Eastern Europe	418	390	377	407	436	470	498	1.3
Total EE/FSU	**1,906**	**1,459**	**1,452**	**1,533**	**1,617**	**1,758**	**1,853**	**1.2**
Developing Countries								
Developing Asia	**1,259**	**2,175**	**2,319**	**2,630**	**3,069**	**3,525**	**3,984**	**2.6**
China	551	1,013	1,084	1,204	1,450	1,698	1,956	2.9
India	257	396	424	492	566	655	745	2.7
South Korea	93	207	233	259	284	316	346	1.9
Other Asia	357	560	578	674	769	855	937	2.3
Middle East	**263**	**470**	**494**	**518**	**592**	**671**	**759**	**2.1**
Turkey	51	102	106	119	134	150	167	2.2
Other Middle East	213	368	388	399	458	521	592	2.0
Africa	**287**	**361**	**367**	**442**	**508**	**587**	**646**	**2.7**
Central and South America	**449**	**656**	**684**	**772**	**887**	**1,014**	**1,157**	**2.5**
Brazil	229	334	354	407	470	530	601	2.6
Other Central/South America	220	322	330	365	418	485	557	2.5
Total Developing	**2,258**	**3,663**	**3,863**	**4,362**	**5,056**	**5,796**	**6,546**	**2.5**
Total World	**10,549**	**12,725**	**12,833**	**14,289**	**15,662**	**17,093**	**18,468**	**1.7**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Electricity consumption equals generation plus imports minus exports minus distribution losses.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table B2; and World Energy Projection System (2001).

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	**1,556**	**1,742**	**1,761**	**1,932**	**2,040**	**2,153**	**2,255**	**1.2**
United States[a]	1,345	1,495	1,511	1,660	1,750	1,840	1,916	1.1
Canada	126	146	150	153	156	160	162	0.4
Mexico	84	101	101	119	134	153	177	2.7
Western Europe	**930**	**947**	**940**	**975**	**992**	**1,009**	**1,032**	**0.4**
United Kingdom	164	154	151	164	169	173	177	0.7
France	102	110	109	113	114	118	122	0.6
Germany	271	237	230	237	240	242	246	0.3
Italy	112	122	121	127	129	130	132	0.4
Netherlands	58	66	64	65	64	66	66	0.1
Other Western Europe	223	260	264	270	276	281	290	0.4
Industrialized Asia	**357**	**412**	**422**	**429**	**432**	**436**	**443**	**0.2**
Japan	269	300	307	309	309	309	313	0.1
Australasia	88	112	115	120	123	126	130	0.9
Total Industrialized	**2,842**	**3,101**	**3,122**	**3,337**	**3,464**	**3,597**	**3,730**	**0.9**
EE/FSU								
Former Soviet Union	1,036	599	607	645	671	727	762	1.1
Eastern Europe	301	217	203	205	206	203	201	0.0
Total EE/FSU	**1,337**	**816**	**810**	**850**	**877**	**930**	**963**	**0.8**
Developing Countries								
Developing Asia	**1,053**	**1,435**	**1,361**	**1,600**	**1,814**	**2,019**	**2,212**	**2.3**
China	617	765	669	788	909	1,016	1,115	2.5
India	153	231	242	283	315	352	389	2.3
South Korea	61	101	107	123	134	146	155	1.8
Other Asia	223	338	343	406	455	505	553	2.3
Middle East	**231**	**325**	**330**	**358**	**403**	**451**	**508**	**2.1**
Turkey	35	50	50	55	61	67	73	1.8
Other Middle East	196	275	280	302	342	384	436	2.1
Africa	**179**	**216**	**218**	**245**	**264**	**284**	**303**	**1.6**
Central and South America	**178**	**246**	**249**	**292**	**346**	**403**	**466**	**3.0**
Brazil	62	87	88	102	124	144	168	3.2
Other Central/South America	116	159	162	191	222	259	298	3.0
Total Developing	**1,641**	**2,222**	**2,158**	**2,495**	**2,826**	**3,157**	**3,490**	**2.3**
Total World	**5,821**	**6,139**	**6,091**	**6,682**	**7,167**	**7,684**	**8,183**	**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. 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, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table B19; and World Energy Projection System (2001).

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**	**842**	**897**	**953**	**1,009**	**1.2**
United States[a]	590	635	650	686	727	764	798	1.0
Canada	61	66	68	70	71	71	70	0.1
Mexico	65	74	76	86	100	118	141	3.0
Western Europe	**474**	**525**	**517**	**532**	**533**	**531**	**525**	**0.1**
United Kingdom	66	65	63	72	73	74	74	0.8
France	67	72	72	73	74	73	71	0.0
Germany	103	107	104	108	107	106	104	0.0
Italy	74	78	74	77	77	76	75	0.0
Netherlands	27	30	31	31	32	32	32	0.2
Other Western Europe	138	172	173	171	171	170	168	-0.1
Industrialized Asia	**217**	**230**	**233**	**233**	**234**	**233**	**233**	**0.0**
Japan	179	183	185	182	180	177	174	-0.3
Australasia	38	46	48	51	53	56	59	1.0
Total Industrialized	**1,407**	**1,529**	**1,543**	**1,606**	**1,664**	**1,716**	**1,767**	**0.6**
EE/FSU								
Former Soviet Union	334	148	146	186	207	246	271	3.0
Eastern Europe	66	55	55	55	56	56	54	0.0
Total EE/FSU	**400**	**202**	**201**	**241**	**263**	**301**	**325**	**2.3**
Developing Countries								
Developing Asia	**304**	**479**	**496**	**579**	**667**	**762**	**852**	**2.6**
China	94	152	160	173	200	229	255	2.3
India	45	70	73	93	116	147	180	4.4
South Korea	38	60	62	73	78	81	84	1.5
Other Asia	127	197	201	239	272	304	333	2.4
Middle East	**155**	**195**	**198**	**210**	**236**	**275**	**329**	**2.4**
Turkey	17	22	22	27	30	33	37	2.6
Other Middle East	138	173	177	183	206	242	292	2.4
Africa	**83**	**95**	**97**	**121**	**138**	**152**	**167**	**2.6**
Central and South America	**132**	**173**	**176**	**190**	**215**	**241**	**271**	**2.1**
Brazil	51	70	71	79	95	112	131	3.0
Other Central/South America	81	104	105	111	120	129	140	1.3
Total Developing	**674**	**942**	**968**	**1,100**	**1,255**	**1,430**	**1,620**	**2.5**
Total World	**2,482**	**2,673**	**2,712**	**2,947**	**3,182**	**3,448**	**3,712**	**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, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table B19; and World Energy Projection System (2001).

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**	**435**	**474**	**518**	**556**	**1.8**
United States[a]	277	315	317	362	397	438	473	1.9
Canada	35	42	46	49	51	54	56	1.0
Mexico	15	20	19	24	26	26	26	1.6
Western Europe	**140**	**196**	**206**	**255**	**282**	**310**	**356**	**2.6**
United Kingdom	30	47	50	57	63	69	78	3.8
France	16	21	21	28	34	38	46	3.8
Germany	32	42	43	55	60	65	77	2.8
Italy	25	32	35	39	43	46	48	1.5
Netherlands	20	23	22	24	25	27	28	1.1
Other Western Europe	18	31	35	51	57	65	79	3.9
Industrialized Asia	**36**	**52**	**54**	**59**	**61**	**65**	**73**	**1.4**
Japan	24	38	40	42	43	45	52	1.3
Australasia	12	14	14	16	18	19	21	1.8
Total Industrialized	**503**	**626**	**641**	**749**	**816**	**893**	**984**	**2.1**
EE/FSU								
Former Soviet Union	369	291	294	305	322	358	384	1.3
Eastern Europe	46	36	35	45	65	86	99	5.1
Total EE/FSU	**414**	**327**	**329**	**349**	**386**	**444**	**483**	**1.8**
Developing Countries								
Developing Asia	**45**	**86**	**92**	**138**	**173**	**216**	**256**	**5.0**
China	8	13	14	28	39	56	71	7.9
India	7	13	12	21	27	33	39	5.5
South Korea	2	8	10	14	17	24	30	5.6
Other Asia	29	53	56	75	91	103	116	3.6
Middle East	**56**	**100**	**102**	**118**	**136**	**145**	**150**	**1.8**
Turkey	2	6	7	8	9	12	15	3.7
Other Middle East	54	94	96	111	126	133	135	1.7
Africa	**22**	**29**	**31**	**35**	**38**	**43**	**46**	**2.0**
Central and South America	**32**	**49**	**51**	**81**	**111**	**142**	**177**	**6.1**
Brazil	2	3	4	9	15	19	24	9.6
Other Central/South America	30	46	47	72	95	123	152	5.7
Total Developing	**155**	**263**	**276**	**372**	**458**	**546**	**629**	**4.0**
Total World	**1,072**	**1,216**	**1,247**	**1,471**	**1,660**	**1,884**	**2,096**	**2.5**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table B19; and World Energy Projection System (2001).

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**	**655**	**668**	**681**	**690**	**0.7**
United States[a]	485	550	549	613	626	638	645	0.8
Canada	31	38	36	34	33	35	36	-0.1
Mexico	4	7	6	9	9	9	10	2.3
Western Europe	**315**	**225**	**216**	**188**	**177**	**168**	**151**	**-1.7**
United Kingdom	68	42	39	35	33	30	24	-2.2
France	20	17	15	11	7	7	4	-5.7
Germany	137	87	83	74	73	70	65	-1.2
Italy	14	11	12	10	10	9	9	-1.5
Netherlands	11	13	11	10	7	7	6	-3.1
Other Western Europe	66	56	56	49	48	45	43	-1.3
Industrialized Asia	**104**	**130**	**135**	**137**	**138**	**138**	**137**	**0.1**
Japan	66	78	81	85	86	87	87	0.3
Australasia	38	52	53	53	52	51	50	-0.2
Total Industrialized	**939**	**951**	**943**	**981**	**984**	**987**	**979**	**0.2**
EE/FSU								
Former Soviet Union	333	160	168	154	142	123	107	-2.1
Eastern Europe	189	127	113	106	85	62	48	-4.0
Total EE/FSU	**522**	**287**	**280**	**260**	**227**	**184**	**155**	**-2.8**
Developing Countries								
Developing Asia	**704**	**870**	**773**	**883**	**974**	**1,042**	**1,103**	**1.7**
China	514	600	495	587	670	731	789	2.2
India	101	148	156	168	172	171	170	0.4
South Korea	21	33	36	37	40	41	41	0.6
Other Asia	67	88	87	91	92	98	103	0.8
Middle East	**20**	**30**	**29**	**29**	**31**	**30**	**29**	**0.1**
Turkey	16	23	21	21	22	22	21	-0.1
Other Middle East	4	7	7	8	9	9	8	0.4
Africa	**74**	**93**	**90**	**90**	**88**	**89**	**89**	**0.0**
Central and South America	**15**	**23**	**22**	**21**	**20**	**19**	**19**	**-0.7**
Brazil	9	14	13	13	13	13	13	-0.1
Other Central/South America	5	9	9	8	7	6	6	-1.7
Total Developing	**812**	**1,017**	**914**	**1,022**	**1,113**	**1,181**	**1,241**	**1.5**
Total World	**2,274**	**2,254**	**2,137**	**2,264**	**2,324**	**2,352**	**2,375**	**0.5**

[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, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table B19; and World Energy Projection System (2001).

Table C14. World Nuclear Generating Capacity by Region and Country, Low Economic Growth Case, 1998-2020
(Megawatts)

Region/Country	History 1998	History 1999	Projections 2005	Projections 2010	Projections 2015	Projections 2020
Industrialized Countries						
North America						
United States	97,133	97,157	96,800	89,900	65,600	55,300
Canada	10,298	9,998	9,998	9,998	8,728	8,728
Mexico	1,308	1,308	1,308	1,308	1,308	1,308
Industrialized Asia						
Japan	43,69	43,69	43,582	43,102	33,672	40,297
Western Europe						
Belgium	5,712	5,712	5,712	3,966	3,966	3,966
Finland	2,656	2,656	2,656	2,656	2,656	1,328
France	61,653	63,103	64,320	63,430	58,960	51,670
Germany	22,282	21,122	18,975	16,179	13,134	5,309
Netherlands	449	449	0	0	0	0
Spain	7,350	7,470	7,317	6,871	6,871	6,871
Sweden	10,040	9,432	7,957	6,907	6,077	3,279
Switzerland	3,079	3,079	2,714	2,000	2,000	1,030
United Kingdom	12,968	12,968	10,992	8,118	4,153	1,763
Total Industrialized	**278,619**	**278,145**	**272,331**	**254,435**	**207,125**	**180,849**
EE/FSU						
Eastern Europe						
Bulgaria	3,538	3,538	2,314	1,906	1,906	1,906
Czech Republic	1,648	1,648	3,472	3,472	3,472	2,236
Hungary	1,729	1,729	1,729	1,729	1,729	866
Romania	650	650	650	650	650	650
Slovak Republic	2,020	2,408	1,592	1,592	1,592	776
Slovenia	632	632	632	632	632	0
Former Soviet Union						
Armenia	376	376	0	0	0	0
Kazakhstan	70	0	0	0	0	0
Lithuania	2,370	2,370	1,185	0	0	0
Russia	19,843	19,843	19,472	15,482	11,222	6,650
Ukraine	13,765	12,115	11,190	11,190	6,650	950
Total EE/FSU	**46,641**	**45,309**	**42,236**	**36,653**	**27,853**	**14,034**

See notes at end of table.

Table C14. World Nuclear Generating Capacity by Region and Country, Low Economic Growth Case, 1998-2020 (Continued)
(Megawatts)

Region/Country	History		Projections			
	1998	1999	2005	2010	2015	2020
Developing Countries						
Developing Asia						
China	2,167	2,167	5,257	8,587	9,587	10,587
India	1,695	1,897	2,113	2,563	4,671	4,516
Korea, South	11,380	12,990	14,890	16,234	18,455	20,150
Pakistan	125	125	300	300	300	300
Taiwan	4,884	4,884	4,884	6,199	6,306	6,306
Central and South America						
Argentina	935	935	600	600	600	0
Brazil	626	626	1,855	1,855	1,229	1,229
Middle East						
Iran	0	0	0	1,073	1,073	1,073
Africa						
South Africa	1,842	1,842	1,842	1,952	1,842	1,842
Total Developing	**23,654**	**25,466**	**31,741**	**39,363**	**44,063**	**46,003**
Total World	**348,914**	**348,920**	**346,308**	**330,451**	**279,041**	**240,886**

Sources: **History:** International Atomic Energy Agency, *Nuclear Power Reactors in the World 1999* (Vienna, Austria, April 2000). **Projections:** Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, based on detailed assessments of country-specific nuclear power plants.

Table C15. World Total Energy Consumption in Oil-Equivalent Units by Region, Low Economic Growth Case, 1990-2020
(Million Tons Oil Equivalent)

Region/Country	History			Projections				Average Annual Percent Change, 1999-2020
	1990	1998	1999	2005	2010	2015	2020	
Industrialized Countries								
North America	**2,517**	**2,850**	**2,915**	**3,178**	**3,352**	**3,501**	**3,638**	**1.1**
United States[a]	2,116	2,385	2,438	2,649	2,783	2,899	2,998	1.0
Canada	275	312	323	349	365	373	377	0.7
Mexico	126	152	155	180	204	230	262	2.6
Western Europe	**1,507**	**1,656**	**1,661**	**1,749**	**1,789**	**1,826**	**1,869**	**0.6**
United Kingdom	231	247	246	260	268	276	282	0.7
France	234	271	275	293	301	307	314	0.6
Germany	373	357	352	373	379	384	391	0.5
Italy	167	190	192	202	208	213	217	0.6
Netherlands	83	93	92	96	98	100	102	0.5
Other Western Europe	419	497	504	524	535	546	562	0.5
Industrialized Asia	**574**	**695**	**704**	**714**	**727**	**749**	**763**	**0.4**
Japan	452	541	547	549	555	571	579	0.3
Australasia	122	153	157	166	172	178	184	0.8
Total Industrialized	**4,598**	**5,201**	**5,281**	**5,641**	**5,867**	**6,076**	**6,270**	**0.8**
EE/FSU								
Former Soviet Union	1,538	978	990	1,055	1,101	1,194	1,250	1.1
Eastern Europe	386	299	284	298	316	337	353	1.1
Total EE/FSU	**1,924**	**1,277**	**1,274**	**1,353**	**1,417**	**1,532**	**1,604**	**1.1**
Developing Countries								
Developing Asia	**1,286**	**1,837**	**1,788**	**2,133**	**2,437**	**2,739**	**3,030**	**2.5**
China	680	892	805	967	1,122	1,267	1,406	2.7
India	196	293	307	367	417	478	538	2.7
South Korea	92	173	185	217	235	259	280	2.0
Other Asia	317	480	490	582	663	736	805	2.4
Middle East	**330**	**481**	**486**	**536**	**606**	**679**	**760**	**2.1**
Turkey	50	75	74	82	92	102	112	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**	**573**	**656**	**747**	**849**	**2.6**
Brazil	136	197	204	228	259	287	321	2.2
Other Central/South America	210	292	294	345	397	460	528	2.8
Total Developing	**2,197**	**3,099**	**3,068**	**3,580**	**4,064**	**4,563**	**5,064**	**0.0**
Total World	**8,719**	**9,577**	**9,622**	**10,574**	**11,349**	**12,170**	**12,937**	**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.
Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table B1; and World Energy Projection System (2001).

Appendix D

Projections of Oil Production Capacity and Oil Production in Five Cases:

- Reference
- High World Oil Price
- Low World Oil Price
- High Non-OPEC Supply
- Low Non-OPEC Supply

Table D1. World Oil Production Capacity by Region and Country, Reference Case, 1990-2020
(Million Barrels per Day)

Region/Country	History (Estimates)		Projections			
	1990	1999	2005	2010	2015	2020
OPEC						
Persian Gulf						
Iran	3.2	3.9	4.0	4.3	4.6	4.8
Iraq	2.2	2.8	3.1	3.8	4.7	5.8
Kuwait	1.7	2.6	2.8	3.5	4.1	5.0
Qatar	0.5	0.6	0.5	0.6	0.7	0.7
Saudi Arabia	8.6	11.4	12.6	14.7	18.4	23.1
United Arab Emitates	2.5	2.7	3.0	3.5	4.4	5.1
Total Persian Gulf	**18.7**	**24.0**	**26.0**	**30.4**	**36.9**	**44.5**
Other OPEC						
Algeria	1.3	1.4	1.9	2.1	2.3	2.5
Indonesia	1.5	1.7	1.5	1.5	1.5	1.5
Libya	1.5	1.5	2.1	2.5	2.8	3.2
Nigeria	1.8	2.2	2.8	3.2	4.0	4.7
Venezuela	2.4	3.4	4.2	4.6	5.0	6.0
Total Other OPEC	**8.5**	**10.2**	**12.5**	**13.9**	**15.6**	**17.9**
Total OPEC	**27.2**	**34.2**	**38.5**	**44.3**	**52.5**	**62.4**
Non-OPEC						
Industrialized						
United States	9.7	9.3	9.0	8.7	9.0	9.3
Canada	2.0	2.7	3.0	3.2	3.4	3.5
Mexico	3.0	3.5	4.1	4.2	4.4	4.4
Australia	0.7	0.8	0.8	0.8	0.8	0.8
North Sea	4.2	6.3	6.6	6.5	6.2	6.0
Other	0.5	0.7	0.8	0.8	0.8	0.7
Total Industrialized	**20.1**	**23.3**	**24.3**	**24.2**	**24.6**	**24.7**
Eurasia						
China	2.8	3.2	3.1	3.1	3.0	3.0
Former Soviet Union	11.4	7.2	9.6	11.9	13.6	14.8
Eastern Europe	0.3	0.3	0.3	0.3	0.3	0.4
Total Eurasia	**14.5**	**10.7**	**13.0**	**15.3**	**16.9**	**18.2**
Other Non-OPEC						
Central and South America	2.3	3.6	4.2	4.8	5.5	6.4
Middle East	1.4	1.9	2.2	2.4	2.5	2.4
Africa	2.2	2.8	3.1	3.8	4.6	5.8
Asia	1.7	2.2	2.6	2.6	2.6	2.5
Total Other Non-OPEC	**7.6**	**10.5**	**12.1**	**13.6**	**15.2**	**17.1**
Total Non-OPEC	**42.2**	**44.5**	**49.4**	**53.1**	**56.7**	**60.0**
Total World	**69.4**	**78.7**	**87.9**	**97.4**	**109.2**	**122.4**

Note: OPEC = Organization of Petroleum Exporting Countries.

Sources: **History:** Energy Information Administration (EIA), Energy Markets and Contingency Information Division. **Projections:** EIA, Office of Integrated Analysis and Forecasting, World Energy Projection System; and 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) 1990	1999	Projections 2005	2010	2015	2020
OPEC						
Persian Gulf						
Iran	3.2	3.9	3.8	4.1	4.2	4.5
Iraq	2.2	2.9	2.9	3.5	4.2	5.1
Kuwait	1.7	2.6	2.6	3.3	3.8	4.5
Qatar	0.5	0.8	0.5	0.6	0.7	0.7
Saudi Arabia	8.6	11.6	11.6	12.7	15.6	19.5
United Arab Emitates	2.5	2.7	2.8	3.1	3.7	4.6
Total Persian Gulf	**18.7**	**24.5**	**24.2**	**27.3**	**32.2**	**38.9**
Other OPEC						
Algeria	1.3	1.4	1.6	1.9	2.1	2.4
Indonesia	1.5	1.7	1.5	1.5	1.5	1.5
Libya	1.5	1.6	1.7	2.1	2.3	2.8
Nigeria	1.8	2.3	2.4	2.8	3.4	4.2
Venezuela	2.4	3.4	3.7	4.2	4.8	5.7
Total Other OPEC	**8.5**	**10.4**	**10.9**	**12.5**	**14.1**	**16.6**
Total OPEC	**27.2**	**34.9**	**35.1**	**39.8**	**46.3**	**55.5**
Non-OPEC						
Industrialized						
United States	9.7	9.0	9.5	9.3	9.8	10.1
Canada	2.0	2.6	3.0	3.2	3.4	3.6
Mexico	3.0	3.4	4.1	4.3	4.5	4.5
Australia	0.7	0.7	0.9	0.9	0.8	0.8
North Sea	4.2	6.3	6.6	6.4	6.3	6.1
Other	0.5	0.8	0.8	0.8	0.8	0.7
Total Industrialized	**20.1**	**22.8**	**24.9**	**24.9**	**25.6**	**25.8**
Eurasia						
China	2.8	3.2	3.1	3.1	3.1	3.1
Former Soviet Union	11.4	7.4	9.8	12.2	13.9	15.1
Eastern Europe	0.3	0.3	0.3	0.3	0.3	0.4
Total Eurasia	**14.5**	**10.9**	**13.2**	**15.6**	**17.3**	**18.6**
Other Non-OPEC						
Central and South America	2.3	3.8	4.2	4.9	5.7	6.6
Middle East	1.4	1.9	2.3	2.4	2.6	2.5
Africa	2.2	2.9	3.2	3.9	4.8	5.9
Asia	1.7	2.3	2.6	2.7	2.6	2.6
Total Other Non-OPEC	**7.6**	**10.9**	**12.3**	**13.9**	**15.7**	**17.6**
Total Non-OPEC	**42.2**	**44.6**	**50.4**	**54.4**	**58.6**	**62.0**
Total World	**69.4**	**79.5**	**85.5**	**94.2**	**104.9**	**117.5**

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	1999	2005	2010	2015	2020
OPEC						
Persian Gulf						
Iran	3.2	3.9	4.2	4.5	4.8	5.0
Iraq	2.2	2.9	3.5	4.2	5.1	6.2
Kuwait	1.7	2.6	3.0	3.7	4.5	5.5
Qatar	0.5	0.8	0.5	0.6	0.7	0.8
Saudi Arabia	8.6	11.6	15.4	19.3	24.4	31.1
United Arab Emitates	2.5	2.7	3.5	4.0	4.8	5.7
Total Persian Gulf	**18.7**	**24.5**	**30.1**	**36.3**	**44.3**	**54.3**
Other OPEC						
Algeria	1.3	1.4	1.9	2.3	2.5	2.8
Indonesia	1.5	1.7	1.5	1.5	1.5	1.5
Libya	1.5	1.6	2.2	2.7	3.2	3.8
Nigeria	1.8	2.3	2.9	3.6	4.4	5.0
Venezuela	2.4	3.4	4.2	4.8	5.5	6.5
Total Other OPEC	8.5	10.4	**12.7**	**14.9**	**17.1**	**19.6**
Total OPEC	**27.2**	**34.9**	**42.8**	**51.2**	**61.4**	**73.9**
Non-OPEC						
Industrialized						
United States	9.7	9.0	8.4	7.9	8.0	8.2
Canada	2.0	2.6	3.0	3.1	3.3	3.4
Mexico	3.0	3.4	4.0	4.1	4.2	4.2
Australia	0.7	0.7	0.8	0.8	0.8	0.8
North Sea	4.2	6.3	6.6	6.4	6.1	5.8
Other	0.5	0.8	0.8	0.8	0.8	0.7
Total Industrialized	**20.1**	**22.8**	**23.6**	**23.1**	**23.2**	**23.1**
Eurasia						
China	2.8	3.2	3.0	3.0	2.9	2.9
Former Soviet Union	11.4	7.4	9.5	11.6	13.2	14.2
Eastern Europe	0.3	0.3	0.3	0.3	0.3	0.3
Total Eurasia	**14.5**	**10.9**	**12.8**	**14.9**	**16.4**	**17.4**
Other Non-OPEC						
Central and South America	2.3	3.8	4.0	4.7	5.4	6.2
Middle East	1.4	1.9	2.2	2.3	2.4	2.3
Africa	2.2	2.9	3.0	3.6	4.4	5.6
Asia	1.7	2.3	2.6	2.5	2.5	2.4
Total Other Non-OPEC	7.6	10.9	**11.8**	**13.1**	**14.7**	**16.5**
Total Non-OPEC	**42.2**	**44.6**	**48.2**	**51.1**	**54.3**	**57.0**
Total World	**69.4**	**79.5**	**91.0**	**102.3**	**115.7**	**130.9**

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 Capacity by Region and Country, High Non-OPEC Supply Case, 1990-2020
(Million Barrels per Day)

Region/Country	History (Estimates)		Projections			
	1990	1999	2005	2010	2015	2020
OPEC						
Persian Gulf						
Iran	3.2	3.9	4.0	4.2	4.6	4.9
Iraq	2.2	2.9	2.9	3.6	4.4	5.3
Kuwait	1.7	2.6	2.8	3.4	3.9	4.6
Qatar	0.5	0.8	0.5	0.6	0.7	0.7
Saudi Arabia	8.6	11.6	11.7	13.3	15.9	18.9
United Arab Emitates	2.5	2.7	2.9	3.4	3.9	4.8
Total Persian Gulf	**18.7**	**24.5**	**24.8**	**28.5**	**33.4**	**39.2**
Other OPEC						
Algeria	1.3	1.4	1.8	2.0	2.3	2.5
Indonesia	1.5	1.7	1.6	1.5	1.5	1.5
Libya	1.5	1.6	1.9	2.2	2.5	2.9
Nigeria	1.8	2.3	2.6	2.9	3.4	4.2
Venezuela	2.4	3.4	3.8	4.3	4.9	5.7
Total Other OPEC	**8.5**	**10.4**	**11.7**	**12.9**	**14.6**	**16.8**
Total OPEC	**27.2**	**34.9**	**36.5**	**41.4**	**48.0**	**56.0**
Non-OPEC						
Industrialized						
United States	9.7	9.0	9.2	9.0	9.4	9.7
Canada	2.0	2.6	3.2	3.5	3.8	4.2
Mexico	3.0	3.4	4.2	4.4	4.6	4.8
Australia	0.7	0.7	0.9	0.9	0.9	0.9
North Sea	4.2	6.3	6.7	6.5	6.3	6.2
Other	0.5	0.8	0.8	0.8	0.8	0.7
Total Industrialized	**20.1**	**22.8**	**25.0**	**25.1**	**25.8**	**26.5**
Eurasia						
China	2.8	3.2	3.2	3.2	3.2	3.3
Former Soviet Union	11.4	7.4	10.1	12.6	14.8	16.4
Eastern Europe	0.3	0.3	0.3	0.3	0.3	0.4
Total Eurasia	**14.5**	**10.9**	**13.6**	**16.1**	**18.3**	**20.1**
Other Non-OPEC						
Central and South America	2.3	3.8	4.3	5.1	6.2	7.3
Middle East	1.4	1.9	2.3	2.5	2.7	2.7
Africa	2.2	2.9	3.3	4.3	5.3	6.8
Asia	1.7	2.3	2.7	2.7	2.7	2.7
Total Other Non-OPEC	**7.6**	**10.9**	**12.6**	**14.6**	**16.9**	**19.5**
Total Non-OPEC	**42.2**	**44.6**	**51.2**	**55.8**	**61.0**	**66.1**
Total World	**69.4**	**79.5**	**87.7**	**97.2**	**109.0**	**122.1**

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 D5. World Oil Production Capacity by Region and Country, Low Non-OPEC Supply Case, 1990-2020
(Million Barrels per Day)

Region/Country	History (Estimates)		Projections			
	1990	1999	2005	2010	2015	2020
OPEC						
Persian Gulf						
Iran	3.2	3.9	4.2	4.3	4.5	4.8
Iraq	2.2	2.9	3.3	3.9	4.6	6.2
Kuwait	1.7	2.6	2.9	3.5	4.2	4.6
Qatar	0.5	0.8	0.5	0.6	0.7	0.8
Saudi Arabia	8.6	11.6	14.1	17.7	23.2	29.3
United Arab Emitates	2.5	2.7	3.4	3.8	4.4	5.0
Total Persian Gulf	**18.7**	**24.5**	**28.4**	**33.8**	**41.6**	**50.7**
Other OPEC						
Algeria	1.3	1.4	1.7	2.1	2.5	2.8
Indonesia	1.5	1.7	1.5	1.5	1.5	1.5
Libya	1.5	1.6	2.0	2.4	3.0	3.9
Nigeria	1.8	2.3	2.7	3.1	3.7	4.5
Venezuela	2.4	3.4	4.2	4.4	4.8	5.5
Total Other OPEC	**8.5**	**10.4**	**12.1**	**13.5**	**15.5**	**18.2**
Total OPEC	**27.2**	**34.9**	**40.5**	**47.3**	**57.1**	**68.9**
Non-OPEC						
Industrialized						
United States	9.7	9.0	8.8	8.4	8.5	8.7
Canada	2.0	2.6	2.9	3.0	3.1	3.2
Mexico	3.0	3.4	3.9	4.0	4.0	4.0
Australia	0.7	0.7	0.8	0.8	0.8	0.7
North Sea	4.2	6.3	6.4	6.2	5.7	5.5
Other	0.5	0.8	0.8	0.8	0.8	0.7
Total Industrialized	**20.1**	**22.8**	**23.6**	**23.2**	**22.9**	**22.8**
Eurasia						
China	2.8	3.2	3.0	2.9	2.8	2.7
Former Soviet Union	11.4	7.4	9.1	11.0	12.2	12.7
Eastern Europe	0.3	0.3	0.3	0.3	0.3	0.3
Total Eurasia	**14.5**	**10.9**	**12.4**	**14.2**	**15.3**	**15.7**
Other Non-OPEC						
Central and South America	2.3	3.8	3.9	4.5	5.1	5.8
Middle East	1.4	1.9	2.2	2.3	2.3	2.2
Africa	2.2	2.9	2.8	3.5	4.2	5.0
Asia	1.7	2.3	2.6	2.5	2.5	2.4
Total Other Non-OPEC	**7.6**	**10.9**	**11.5**	**12.8**	**14.1**	**15.4**
Total Non-OPEC	**42.2**	**44.6**	**47.5**	**50.2**	**52.3**	**53.9**
Total World	**69.4**	**79.5**	**88.0**	**97.5**	**109.4**	**122.8**

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 D6. World Oil Production by Region and Country, Reference Case, 1990-2020
(Million Barrels per Day)

Region/Country	History (Estimates)		Projections			
	1990	1999	2005	2010	2015	2020
OPEC						
Persian Gulf	16.2	19.9	23.8	28.5	34.6	41.5
Other OPEC	8.3	9.4	11.6	13.1	15.3	17.8
Total OPEC	**24.5**	**29.3**	**35.4**	**41.6**	**49.9**	**59.3**
Non-OPEC						
Industrialized						
United States	9.7	9.0	9..0	8.7	9.0	9.3
Canada	2.0	2.6	3.0	3.2	3.4	3.5
Mexico	3.0	3.4	4.1	4.2	4.4	4.4
Western Europe	4.6	7.0	7.3	7.2	6.9	6.6
Other	0.8	0.8	0.9	0.9	0.9	0.9
Total Industrialized	**20.1**	**22.8**	**24.3**	**24.2**	**24.6**	**24.7**
Eurasia						
China	2.8	3.2	3.1	3.1	3.0	3.0
Former Soviet Union	11.4	7.4	9.6	11.9	13.6	14.8
Eastern Europe	0.3	0.3	0.3	0.3	0.3	0.4
Total Eurasia	**14.5**	**10.9**	**13.0**	**15.3**	**16.9**	**18.2**
Other Non-OPEC						
Central and South America	2.4	3.8	4.2	4.8	5.5	6.4
Pacific Rim	1.7	2.3	2.6	2.6	2.6	2.5
Other	3.5	4.8	5.3	6.2	7.1	8.2
Total Other Non-OPEC	**7.6**	**10.9**	**12.1**	**13.6**	**15.2**	**17.1**
Total Non-OPEC	**42.2**	**44.6**	**49.4**	**53.1**	**56.7**	**60.0**
Total World	**66.7**	**73.9**	**84.8**	**94.7**	**106.6**	**119.3**
Persian Gulf Production as a Percentage of World Consumption	**24.6**	**26.6**	**28.0**	**30.0**	**32.4**	**34.7**

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 D7. World Oil Production by Region and Country, High Oil Price Case, 1990-2020
(Million Barrels per Day)

Region/Country	History (Estimates)		Projections			
	1990	1999	2005	2010	2015	2020
OPEC						
Persian Gulf	16.2	19.9	21.4	25.3	30.3	36.3
Other OPEC	8.3	9.4	10.9	12.1	13.7	16.4
Total OPEC	**24.5**	**29.3**	**32.3**	**37.4**	**44.0**	**52.7**
Non-OPEC						
Industrialized						
United States	9.7	9.0	9.5	9.3	9.8	10.1
Canada	2.0	2.6	3.0	3.2	3.4	3.6
Mexico	3.0	3.4	4.1	4.3	4.5	4.5
Western Europe	4.6	7.0	7.4	7.2	7.0	6.7
Other	0.8	0.8	0.9	0.9	0.9	0.9
Total Industrialized	**20.1**	**22.8**	**24.9**	**24.9**	**25.6**	**25.8**
Eurasia						
China	2.8	3.2	3.1	3.1	3.1	3.1
Former Soviet Union	11.4	7.4	9.8	12.2	13.9	15.1
Eastern Europe	0.3	0.3	0.3	0.3	0.3	0.4
Total Eurasia	**14.5**	**10.9**	**13.2**	**15.6**	**17.3**	**18.6**
Other Non-OPEC						
Central and South America	2.4	3.8	4.2	4.9	5.7	6.6
Pacific Rim	1.7	2.3	2.6	2.7	2.6	2.6
Other	3.5	4.8	5.5	6.3	7.4	8.4
Total Other Non-OPEC	**7.6**	**10.9**	**12.3**	**13.9**	**15.7**	**17.6**
Total Non-OPEC	**42.2**	**44.6**	**50.4**	**54.4**	**58.6**	**62.0**
Total World	**66.7**	**73.9**	**82.7**	**91.8**	**102.6**	**114.7**
Persian Gulf Production as a Percentage of World Consumption	**24.6**	**26.6**	**25.8**	**27.5**	**29.5**	**31.6**

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).

Table D8. World Oil Production by Region and Country, Low Oil Price Case, 1990-2020
(Million Barrels per Day)

Region/Country	History (Estimates)		Projections			
	1990	1999	2005	2010	2015	2020
OPEC						
Persian Gulf	16.2	19.9	26.8	33.4	41.5	50.8
Other OPEC	8.3	9.4	12.6	14.8	17.0	19.5
Total OPEC	**24.5**	**29.3**	**39.4**	**48.2**	**58.5**	**70.3**
Non-OPEC						
Industrialized						
United States	9.7	9.0	8.4	7.9	8.0	8.2
Canada	2.0	2.6	3.0	3.1	3.3	3.4
Mexico	3.0	3.4	4.0	4.1	4.2	4.2
Western Europe	4.6	7.0	7.3	7.1	6.8	6.5
Other	0.8	0.8	0.9	0.9	0.9	0.8
Total Industrialized	**20.1**	**22.8**	**23.6**	**23.1**	**23.2**	**23.1**
Eurasia						
China	2.8	3.2	3.0	3.0	2.9	2.9
Former Soviet Union	11.4	7.4	9.5	11.6	13.2	14.2
Eastern Europe	0.3	0.3	0.3	0.3	0.3	0.3
Total Eurasia	**14.5**	**10.9**	**12.8**	**14.9**	**16.4**	**17.4**
Other Non-OPEC						
Central and South America	2.4	3.8	4.0	4.7	5.4	6.2
Pacific Rim	1.7	2.3	2.6	2.5	2.5	2.4
Other	3.5	4.8	5.2	5.9	6.8	7.9
Total Other Non-OPEC	**7.6**	**10.9**	**11.8**	**13.1**	**14.7**	**16.5**
Total Non-OPEC	**42.2**	**44.6**	**48.2**	**51.1**	**54.3**	**57.0**
Total World	**66.7**	**73.9**	**87.6**	**99.3**	**112.8**	**127.3**
Persian Gulf Production as a Percentage of World Consumption	**24.6**	**26.6**	**30.5**	**33.5**	**36.7**	**39.8**

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 D9. World Oil Production by Region and Country, High Non-OPEC Supply Case, 1990-2020
(Million Barrels per Day)

Region/Country	History (Estimates)		Projections			
	1990	1999	2005	2010	2015	2020
OPEC						
Persian Gulf	16.2	19.9	22.4	26.3	31.3	36.6
Other OPEC	8.3	9.4	11.2	12.6	14.3	16.6
Total OPEC	**24.5**	**29.3**	**33.6**	**38.9**	**45.6**	**53.2**
Non-OPEC						
Industrialized						
United States	9.7	9.0	9.2	9.0	9.4	9.7
Canada	2.0	2.6	3.2	3.5	3.8	4.2
Mexico	3.0	3.4	4.2	4.4	4.6	4.8
Western Europe	4.6	7.0	7.4	7.3	7.1	6.9
Other	0.8	0.8	1.0	0.9	0.9	0.9
Total Industrialized	**20.1**	**22.8**	**25.0**	**25.1**	**25.8**	**26.5**
Eurasia						
China	2.8	3.2	3.2	3.2	3.2	3.3
Former Soviet Union	11.4	7.4	10.1	12.6	14.8	16.4
Eastern Europe	0.3	0.3	0.3	0.3	0.3	0.4
Total Eurasia	**14.5**	**10.9**	**13.6**	**16.1**	**18.3**	**20.1**
Other Non-OPEC						
Central and South America	2.4	3.8	4.3	5.1	6.2	7.3
Pacific Rim	1.7	2.3	2.7	2.7	2.7	2.7
Other	3.5	4.8	5.6	6.8	8.0	9.5
Total Other Non-OPEC	**7.6**	**10.9**	**12.6**	**14.6**	**16.9**	**19.5**
Total Non-OPEC	**42.2**	**44.6**	**51.2**	**55.8**	**61.0**	**66.1**
Total World	**66.7**	**73.9**	**84.8**	**94.7**	**106.6**	**119.3**
Persian Gulf Production as a Percentage of World Consumption	**24.6**	**26.6**	**26.3**	**27.7**	**29.3**	**30.6**

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).

Table D10. World Oil Production by Region and Country, Low Non-OPEC Supply Case, 1990-2020
(Million Barrels per Day)

Region/Country	History (Estimates)		Projections			
	1990	1999	2005	2010	2015	2020
OPEC						
Persian Gulf	16.2	19.9	25.2	31.1	38.9	47.3
Other OPEC	8.3	9.4	12.1	13.4	15.4	18.1
Total OPEC	**24.5**	**29.3**	**37.3**	**44.5**	**54.3**	**65.4**
Non-OPEC						
Industrialized						
United States	9.7	9.0	8.8	8.4	8.5	8.7
Canada	2.0	2.6	2.9	3.0	3.1	3.2
Mexico	3.0	3.4	3.9	4.0	4.0	4.0
Western Europe	4.6	7.0	7.1	6.9	6.5	6.1
Other	0.8	0.8	0.9	0.9	0.8	0.8
Total Industrialized	**20.1**	**22.8**	**23.6**	**23.2**	**22.9**	**22.8**
Eurasia						
China	2.8	3.2	3.0	2.9	2.8	2.7
Former Soviet Union	11.4	7.4	9.1	11.0	12.2	12.7
Eastern Europe	0.3	0.3	0.3	0.3	0.3	0.3
Total Eurasia	**14.5**	**10.9**	**12.4**	**14.2**	**15.3**	**15.7**
Other Non-OPEC						
Central and South America	2.4	3.8	3.9	4.5	5.1	5.8
Pacific Rim	1.7	2.3	2.6	2.5	2.5	2.4
Other	3.5	4.8	5.0	5.8	6.5	7.2
Total Other Non-OPEC	**7.6**	**10.9**	**11.5**	**12.8**	**14.1**	**15.4**
Total Non-OPEC	**42.2**	**44.6**	**47.5**	**50.2**	**52.3**	**53.9**
Total World	**66.7**	**73.9**	**84.8**	**94.7**	**106.6**	**119.3**
Persian Gulf Production as a Percentage of World Consumption	**24.6**	**26.6**	**29.6**	**32.7**	**36.4**	**39.5**

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	**12.6**	**14.7**	**15.1**	**17.4**	**19.2**	**21.1**	**23.1**	**2.0**
United States[a]	11.0	12.8	13.2	15.1	16.6	17.9	19.3	1.8
Canada	0.9	1.1	1.1	1.2	1.3	1.3	1.4	1.2
Mexico	0.6	0.8	0.8	1.1	1.4	1.8	2.4	5.2
Western Europe	**6.2**	**7.2**	**7.3**	**7.9**	**8.4**	**8.7**	**9.0**	**1.0**
United Kingdom	1.0	1.1	1.1	1.2	1.3	1.4	1.5	1.5
France	0.9	1.0	1.1	1.2	1.2	1.3	1.3	1.1
Germany	1.2	1.4	1.4	1.5	1.6	1.6	1.7	0.9
Italy	0.7	0.8	0.9	0.9	0.9	1.0	1.0	0.6
Netherlands	0.4	0.5	0.5	0.5	0.6	0.6	0.6	1.0
Other Western Europe	2.0	2.3	2.4	2.6	2.7	2.8	2.9	1.0
Industrialized Asia	**2.1**	**2.6**	**2.6**	**2.8**	**3.0**	**3.1**	**3.2**	**1.0**
Japan	1.6	1.9	2.0	2.1	2.1	2.2	2.2	0.7
Australasia	0.5	0.6	0.7	0.7	0.8	0.9	0.9	1.8
Total Industrialized	**20.9**	**24.4**	**25.0**	**28.1**	**30.5**	**32.8**	**35.3**	**1.6**
EE/FSU								
Former Soviet Union	2.7	1.4	1.4	1.8	2.1	2.4	2.6	2.9
Eastern Europe	0.6	0.6	0.6	0.8	0.9	1.0	1.1	2.6
Total EE/FSU	**3.3**	**2.0**	**2.1**	**2.6**	**3.0**	**3.4**	**3.7**	**2.8**
Developing Countries								
Developing Asia	**3.1**	**5.3**	**5.6**	**7.7**	**9.9**	**12.9**	**16.1**	**5.1**
China	0.8	1.4	1.5	2.1	3.0	4.3	5.7	6.7
India	0.5	0.9	1.0	1.5	2.2	3.2	4.3	7.3
South Korea	0.3	0.7	0.8	0.9	1.1	1.2	1.3	2.5
Other Asia	1.4	2.3	2.4	3.1	3.7	4.2	4.8	3.3
Middle East	**1.2**	**1.8**	**1.8**	**2.2**	**2.7**	**3.6**	**4.8**	**4.8**
Turkey	0.2	0.3	0.3	0.4	0.4	0.4	0.5	2.4
Other Middle East	1.0	1.5	1.5	1.8	2.3	3.1	4.3	5.2
Africa	**0.9**	**1.1**	**1.2**	**1.5**	**1.7**	**1.9**	**2.2**	**3.0**
Central and South America	**1.6**	**2.1**	**2.1**	**2.8**	**3.5**	**4.4**	**5.5**	**4.6**
Brazil	0.7	0.9	0.9	1.1	1.5	1.8	2.3	4.8
Other Central/South America	0.9	1.3	1.3	1.7	2.1	2.6	3.2	4.5
Total Developing	**6.8**	**10.4**	**10.7**	**14.2**	**17.9**	**22.8**	**28.6**	**4.8**
Total World	**31.0**	**36.8**	**37.8**	**44.9**	**51.4**	**59.1**	**67.5**	**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, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table A2; and World Energy Projection System (2001).

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	**7.6**	**8.9**	**9.1**	**10.2**	**11.1**	**12.0**	**13.0**	**1.7**
United States[a]	6.6	7.8	8.0	8.9	9.5	10.1	10.7	1.4
Canada	0.5	0.6	0.6	0.7	0.7	0.7	0.7	1.0
Mexico	0.4	0.5	0.6	0.7	0.9	1.2	1.6	5.1
Western Europe	**2.6**	**2.8**	**2.8**	**3.0**	**3.0**	**3.0**	**3.0**	**0.3**
United Kingdom	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.5
France	0.4	0.3	0.3	0.4	0.4	0.4	0.4	0.2
Germany	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.3
Italy	0.3	0.4	0.4	0.4	0.4	0.4	0.4	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	0.9	0.9	0.9	0.9	0.3
Industrialized Asia	**1.0**	**1.2**	**1.2**	**1.3**	**1.3**	**1.3**	**1.3**	**0.4**
Japan	0.7	0.8	0.8	0.9	0.9	0.9	0.9	0.1
Australasia	0.3	0.3	0.3	0.4	0.4	0.4	0.4	1.1
Total Industrialized	**11.2**	**12.9**	**13.1**	**14.5**	**15.4**	**16.4**	**17.3**	**1.3**
EE/FSU								
Former Soviet Union	1.1	0.4	0.4	0.6	0.7	0.8	0.8	2.9
Eastern Europe	0.3	0.3	0.3	0.4	0.5	0.5	0.5	2.1
Total EE/FSU	**1.3**	**0.7**	**0.8**	**1.0**	**1.2**	**1.3**	**1.3**	**2.6**
Developing Countries								
Developing Asia	**1.0**	**1.8**	**1.9**	**2.6**	**3.4**	**4.5**	**5.5**	**5.2**
China	0.4	0.8	0.8	1.2	1.8	2.6	3.4	7.1
India	0.1	0.1	0.1	0.2	0.3	0.4	0.5	6.7
South Korea	0.1	0.2	0.2	0.2	0.3	0.3	0.3	2.0
Other Asia	0.4	0.7	0.8	1.0	1.1	1.2	1.3	2.4
Middle East	**0.6**	**0.8**	**0.8**	**1.0**	**1.2**	**1.6**	**2.3**	**5.3**
Turkey	0.1	0.1	0.1	0.1	0.1	0.2	0.2	1.6
Other Middle East	0.5	0.7	0.7	0.8	1.1	1.5	2.1	5.7
Africa	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**2.8**
Central and South America	**0.6**	**0.9**	**0.9**	**1.2**	**1.6**	**2.0**	**2.5**	**4.8**
Brazil	0.1	0.2	0.2	0.3	0.4	0.5	0.6	5.0
Other Central/South America	0.5	0.7	0.7	0.9	1.2	1.5	1.8	4.7
Total Developing	**2.5**	**4.0**	**4.1**	**5.5**	**7.0**	**9.0**	**11.2**	**4.9**
Total World	**15.1**	**17.6**	**18.0**	**21.0**	**23.6**	**26.6**	**29.8**	**2.4**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

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

Sources: **History:** Derived from Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table A2; and World Energy Projection System (2001).

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	**2.4**	**2.9**	**3.0**	**3.7**	**4.1**	**4.5**	**5.0**	**2.3**
United States[a]	2.0	2.5	2.6	3.1	3.5	3.8	4.1	2.3
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	0.3	0.4	0.6	4.8
Western Europe	**2.2**	**2.7**	**2.8**	**3.1**	**3.2**	**3.4**	**3.5**	**1.0**
United Kingdom	0.3	0.3	0.4	0.4	0.4	0.5	0.5	1.5
France	0.4	0.5	0.5	0.6	0.6	0.7	0.7	1.2
Germany	0.4	0.5	0.5	0.6	0.6	0.7	0.7	1.2
Italy	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.6
Netherlands	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.8
Other Western Europe	0.7	0.9	0.9	1.0	1.0	1.1	1.1	0.8
Industrialized Asia	**0.6**	**0.8**	**0.8**	**0.9**	**1.0**	**1.0**	**1.0**	**1.1**
Japan	0.5	0.7	0.7	0.8	0.8	0.8	0.8	0.9
Australasia	0.1	0.1	0.1	0.2	0.2	0.2	0.2	2.0
Total Industrialized	**5.2**	**6.5**	**6.6**	**7.6**	**8.3**	**8.9**	**9.5**	**1.7**
EE/FSU								
Former Soviet Union	0.6	0.3	0.4	0.5	0.6	0.7	0.7	3.3
Eastern Europe	0.2	0.2	0.2	0.3	0.3	0.4	0.4	2.8
Total EE/FSU	**0.8**	**0.6**	**0.6**	**0.8**	**0.9**	**1.0**	**1.1**	**3.1**
Developing Countries								
Developing Asia	**1.2**	**2.3**	**2.5**	**3.5**	**4.5**	**5.9**	**7.5**	**5.4**
China	0.2	0.3	0.4	0.5	0.8	1.2	1.7	7.5
India	0.4	0.7	0.8	1.2	1.7	2.5	3.5	7.4
South Korea	0.2	0.4	0.4	0.5	0.5	0.6	0.6	2.2
Other Asia	0.5	0.9	1.0	1.2	1.4	1.6	1.7	2.8
Middle East	**0.3**	**0.6**	**0.6**	**0.7**	**0.9**	**1.1**	**1.5**	**4.9**
Turkey	0.1	0.1	0.2	0.2	0.2	0.2	0.2	2.0
Other Middle East	0.2	0.4	0.4	0.5	0.7	0.9	1.3	5.7
Africa	**0.3**	**0.3**	**0.3**	**0.4**	**0.5**	**0.5**	**0.6**	**3.0**
Central and South America	**0.4**	**0.6**	**0.6**	**0.7**	**0.9**	**1.1**	**1.3**	**4.1**
Brazil	0.1	0.1	0.2	0.2	0.2	0.2	0.2	2.0
Other Central/South America	0.3	0.4	0.4	0.5	0.7	0.9	1.1	4.8
Total Developing	**2.2**	**3.8**	**3.9**	**5.3**	**6.7**	**8.6**	**10.9**	**5.0**
Total World	**8.3**	**10.8**	**11.1**	**13.7**	**15.9**	**18.6**	**21.5**	**3.2**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

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

Sources: **History:** Derived from Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table A2; and World Energy Projection System (2001).

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	**1.7**	**1.8**	**1.9**	**2.1**	**2.5**	**2.9**	**3.3**	**2.8**
United States[a]	1.6	1.7	1.7	2.0	2.3	2.6	3.0	2.6
Canada	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1.3
Mexico	0.0	0.1	0.1	0.1	0.1	0.2	0.2	6.7
Western Europe	**0.6**	**0.8**	**0.8**	**1.1**	**1.2**	**1.4**	**1.6**	**3.2**
United Kingdom	0.1	0.2	0.2	0.2	0.3	0.3	0.4	3.7
France	0.1	0.1	0.1	0.1	0.2	0.2	0.2	3.0
Germany	0.1	0.1	0.1	0.2	0.2	0.2	0.2	2.9
Italy	0.0	0.1	0.1	0.1	0.1	0.1	0.1	2.8
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	3.3
Industrialized Asia	**0.2**	**0.3**	**0.3**	**0.4**	**0.4**	**0.5**	**0.5**	**2.5**
Japan	0.1	0.2	0.2	0.2	0.2	0.3	0.3	1.8
Australasia	0.1	0.1	0.1	0.1	0.2	0.2	0.2	3.5
Total Industrialized	**2.5**	**3.0**	**3.0**	**3.5**	**4.1**	**4.8**	**5.5**	**2.9**
EE/FSU								
Former Soviet Union	0.4	0.2	0.2	0.3	0.3	0.4	0.6	4.7
Eastern Europe	0.0	0.0	0.0	0.1	0.1	0.1	0.1	5.9
Total EE/FSU	**0.5**	**0.2**	**0.2**	**0.3**	**0.4**	**0.5**	**0.7**	**4.9**
Developing Countries								
Developing Asia	**0.3**	**0.5**	**0.5**	**0.8**	**1.1**	**1.6**	**2.1**	**6.9**
China	0.0	0.1	0.1	0.1	0.2	0.2	0.3	6.8
India	0.0	0.1	0.1	0.1	0.1	0.2	0.3	8.0
South Korea	0.0	0.0	0.0	0.1	0.1	0.1	0.2	6.4
Other Asia	0.2	0.3	0.3	0.5	0.7	1.0	1.3	6.7
Middle East	**0.1**	**0.2**	**0.2**	**0.2**	**0.3**	**0.4**	**0.6**	**6.5**
Turkey	0.0	0.0	0.0	0.0	0.1	0.1	0.1	6.4
Other Middle East	0.1	0.1	0.1	0.2	0.2	0.3	0.5	6.5
Africa	**0.1**	**0.1**	**0.1**	**0.2**	**0.2**	**0.3**	**0.4**	**5.0**
Central and South America	**0.1**	**0.2**	**0.2**	**0.2**	**0.3**	**0.4**	**0.5**	**6.0**
Brazil	0.0	0.0	0.0	0.1	0.1	0.1	0.2	6.2
Other Central/South America	0.1	0.1	0.1	0.2	0.2	0.3	0.3	5.9
Total Developing	**0.6**	**0.9**	**1.0**	**1.4**	**2.0**	**2.7**	**3.6**	**6.4**
Total World	**3.6**	**4.1**	**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, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table A2; and World Energy Projection System (2001).

Table E5. World Total Residual Fuel Consumption for Transportation by Region, Reference Case, 1990-2020
(Million Barrels of Oil per Day)

Region/Country	History 1990	History 1998	History 1999	Projections 2005	Projections 2010	Projections 2015	Projections 2020	Average Annual Percent Change, 1999-2020
Industrialized Countries								
North America	**0.5**	**0.4**	**0.4**	**0.5**	**0.5**	**0.5**	**0.5**	**0.7**
United States[a]	0.5	0.3	0.4	0.4	0.4	0.4	0.4	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	0.8
Western Europe	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.3**
United Kingdom	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
France	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.3
Germany	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Italy	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Netherlands	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3
Other Western Europe	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3
Industrialized Asia	**0.1**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.4**
Japan	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.4
Australasia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
Total Industrialized	**1.2**	**1.1**	**1.2**	**1.2**	**1.2**	**1.3**	**1.3**	**0.5**
EE/FSU								
Former Soviet Union	0.2	0.1	0.1	0.1	0.1	0.1	0.1	2.2
Eastern Europe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9
Total EE/FSU	**0.2**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**2.1**
Developing Countries								
Developing Asia	**0.3**	**0.5**	**0.5**	**0.6**	**0.7**	**0.7**	**0.8**	**1.8**
China	0.0	0.1	0.1	0.1	0.1	0.1	0.1	2.5
India	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2
South Korea	0.0	0.1	0.1	0.2	0.2	0.2	0.2	1.6
Other Asia	0.3	0.3	0.3	0.4	0.4	0.4	0.5	1.8
Middle East	**0.2**	**0.3**	**0.3**	**0.3**	**0.4**	**0.4**	**0.4**	**1.7**
Turkey	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5
Other Middle East	0.2	0.3	0.3	0.3	0.3	0.4	0.4	1.7
Africa	**0.1**	**0.1**	**0.1**	**0.1**	**0.2**	**0.2**	**0.2**	**1.3**
Central and South America	**0.1**	**0.1**	**0.1**	**0.2**	**0.2**	**0.2**	**0.2**	**0.9**
Brazil	0.0	0.0	0.0	0.1	0.1	0.1	0.1	1.1
Other Central/South America	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.8
Total Developing	**0.8**	**1.1**	**1.1**	**1.2**	**1.3**	**1.4**	**1.6**	**1.6**
Total World	**2.2**	**2.3**	**2.3**	**2.5**	**2.7**	**2.8**	**2.9**	**1.1**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

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

Sources: **History:** Derived from Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table A2; and World Energy Projection System (2001).

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	**0.4**	**0.7**	**0.7**	**0.9**	**1.1**	**1.2**	**1.3**	**2.8**
United States[a]	0.3	0.5	0.6	0.7	0.9	1.0	1.1	3.1
Canada	0.1	0.2	0.2	0.2	0.2	0.2	0.2	1.5
Mexico	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.7
Western Europe	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.4**
United Kingdom	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
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	0.1
Italy	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.4
Netherlands	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
Other Western Europe	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.4
Industrialized Asia	**0.1**	**0.1**	**0.1**	**0.2**	**0.2**	**0.2**	**0.2**	**0.8**
Japan	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.5
Australasia	0.0	0.0	0.0	0.0	0.0	0.1	0.1	1.4
Total Industrialized	**0.8**	**1.1**	**1.2**	**1.4**	**1.5**	**1.7**	**1.8**	**2.1**
EE/FSU								
Former Soviet Union	0.5	0.4	0.4	0.4	0.4	0.5	0.5	1.2
Eastern Europe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3
Total EE/FSU	**0.5**	**0.4**	**0.4**	**0.5**	**0.5**	**0.5**	**0.6**	**1.2**
Developing Countries								
Developing Asia	**0.4**	**0.3**	**0.3**	**0.3**	**0.4**	**0.4**	**0.4**	**1.3**
China	0.2	0.2	0.2	0.2	0.2	0.2	0.2	1.1
India	0.1	0.0	0.0	0.0	0.0	0.0	0.0	1.2
South Korea	0.0	0.1	0.1	0.1	0.1	0.1	0.1	2.0
Other Asia	0.0	0.1	0.1	0.1	0.1	0.1	0.1	1.2
Middle East	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**1.6**
Turkey	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6
Other Middle East	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.7
Africa	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**3.0**
Central and South America	**0.1**	**0.2**	**0.2**	**0.2**	**0.3**	**0.4**	**0.5**	**4.7**
Brazil	0.1	0.1	0.1	0.2	0.2	0.3	0.4	4.9
Other Central/South America	0.0	0.0	0.0	0.0	0.1	0.1	0.1	3.8
Total Developing	**0.5**	**0.5**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**2.8**
Total World	**1.8**	**2.1**	**2.1**	**2.4**	**2.7**	**3.0**	**3.3**	**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, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table A2; and World Energy Projection System (2001).

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	**9.4**	**11.3**	**11.6**	**13.3**	**14.7**	**16.0**	**17.4**	**2.0**
United States[a]	8.1	9.8	10.0	11.5	12.5	13.4	14.3	1.7
Canada	0.7	0.8	0.8	0.9	0.9	1.0	1.0	1.2
Mexico	0.6	0.7	0.7	1.0	1.2	1.6	2.1	5.1
Western Europe	**4.6**	**5.3**	**5.4**	**5.8**	**6.1**	**6.2**	**6.3**	**0.7**
United Kingdom	0.7	0.8	0.8	0.9	0.9	1.0	1.0	1.0
France	0.7	0.8	0.9	0.9	1.0	1.0	1.0	0.9
Germany	1.0	1.1	1.2	1.3	1.3	1.3	1.4	0.7
Italy	0.6	0.7	0.7	0.8	0.8	0.8	0.8	0.4
Netherlands	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.8
Other Western Europe	1.4	1.6	1.6	1.8	1.8	1.8	1.9	0.6
Industrialized Asia	**1.6**	**2.0**	**2.0**	**2.1**	**2.2**	**2.3**	**2.3**	**0.7**
Japan	1.2	1.5	1.5	1.6	1.7	1.7	1.7	0.5
Australasia	0.4	0.5	0.5	0.5	0.6	0.6	0.6	1.4
Total Industrialized	**15.6**	**18.6**	**19.0**	**21.3**	**22.9**	**24.5**	**26.0**	**1.5**
EE/FSU								
Former Soviet Union	1.5	0.6	0.7	1.0	1.1	1.3	1.4	3.3
Eastern Europe	0.5	0.5	0.5	0.7	0.8	0.8	0.9	2.4
Total EE/FSU	**2.0**	**1.1**	**1.2**	**1.7**	**1.9**	**2.1**	**2.2**	**2.9**
Developing Countries								
Developing Asia	**2.0**	**3.8**	**4.1**	**5.7**	**7.5**	**10.0**	**12.5**	**5.5**
China	0.5	0.9	1.0	1.6	2.4	3.6	4.9	7.8
India	0.4	0.8	0.9	1.3	1.9	2.9	3.9	7.5
South Korea	0.2	0.5	0.5	0.7	0.8	0.8	0.9	2.3
Other Asia	0.9	1.6	1.7	2.1	2.4	2.7	2.9	2.7
Middle East	**0.8**	**1.3**	**1.3**	**1.6**	**2.1**	**2.7**	**3.8**	**5.2**
Turkey	0.2	0.2	0.3	0.3	0.3	0.4	0.4	1.8
Other Middle East	0.7	1.1	1.1	1.3	1.7	2.4	3.4	5.7
Africa	**0.6**	**0.8**	**0.8**	**1.1**	**1.2**	**1.4**	**1.5**	**2.9**
Central and South America	**1.3**	**1.8**	**1.8**	**2.3**	**3.0**	**3.8**	**4.8**	**4.8**
Brazil	0.6	0.7	0.7	1.0	1.3	1.6	2.1	5.0
Other Central/South America	0.7	1.0	1.0	1.4	1.7	2.2	2.7	4.7
Total Developing	**4.7**	**7.7**	**7.9**	**10.8**	**13.8**	**17.9**	**22.5**	**5.1**
Total World	**22.3**	**27.3**	**28.1**	**33.7**	**38.7**	**44.5**	**50.8**	**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.

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

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	**1.5**	**1.6**	**1.6**	**1.9**	**2.2**	**2.6**	**3.0**	**3.0**
United States[a]	1.3	1.4	1.5	1.7	1.9	2.3	2.6	2.8
Canada	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1.3
Mexico	0.0	0.1	0.1	0.1	0.1	0.2	0.2	6.7
Western Europe	**0.6**	**0.8**	**0.8**	**1.1**	**1.2**	**1.4**	**1.7**	**3.2**
United Kingdom	0.1	0.2	0.2	0.2	0.3	0.3	0.4	3.7
France	0.1	0.1	0.1	0.1	0.2	0.2	0.2	3.0
Germany	0.1	0.1	0.1	0.2	0.2	0.2	0.2	2.9
Italy	0.0	0.1	0.1	0.1	0.1	0.1	0.1	2.8
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	3.3
Industrialized Asia	**0.2**	**0.3**	**0.3**	**0.4**	**0.4**	**0.5**	**0.5**	**2.5**
Japan	0.1	0.2	0.2	0.2	0.2	0.3	0.3	1.8
Australasia	0.1	0.1	0.1	0.1	0.2	0.2	0.2	3.5
Total Industrialized	**2.3**	**2.7**	**2.8**	**3.3**	**3.8**	**4.5**	**5.2**	**3.0**
EE/FSU								
Former Soviet Union	0.4	0.2	0.2	0.3	0.3	0.4	0.6	4.7
Eastern Europe	0.0	0.0	0.0	0.1	0.1	0.1	0.1	5.9
Total EE/FSU	**0.5**	**0.2**	**0.2**	**0.3**	**0.4**	**0.6**	**0.7**	**4.9**
Developing Countries								
Developing Asia	**0.3**	**0.5**	**0.5**	**0.8**	**1.1**	**1.6**	**2.1**	**6.9**
China	0.0	0.1	0.1	0.1	0.2	0.2	0.3	6.8
India	0.0	0.1	0.1	0.1	0.1	0.2	0.3	8.0
South Korea	0.0	0.0	0.0	0.1	0.1	0.1	0.2	6.4
Other Asia	0.2	0.3	0.3	0.5	0.7	1.0	1.3	6.7
Middle East	**0.1**	**0.2**	**0.2**	**0.2**	**0.3**	**0.4**	**0.6**	**6.5**
Turkey	0.0	0.0	0.0	0.0	0.1	0.1	0.1	6.4
Other Middle East	0.1	0.1	0.1	0.2	0.2	0.3	0.5	6.5
Africa	**0.1**	**0.1**	**0.1**	**0.2**	**0.2**	**0.3**	**0.4**	**5.0**
Central and South America	**0.1**	**0.2**	**0.2**	**0.2**	**0.3**	**0.4**	**0.5**	**6.0**
Brazil	0.0	0.0	0.0	0.1	0.1	0.1	0.2	6.2
Other Central/South America	0.1	0.1	0.1	0.2	0.2	0.3	0.3	5.9
Total Developing	**0.6**	**0.9**	**1.0**	**1.4**	**2.0**	**2.7**	**3.6**	**6.4**
Total World	**3.4**	**3.9**	**4.0**	**5.0**	**6.2**	**7.7**	**9.4**	**4.2**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. 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, January 2001). **Projections:** EIA, World Energy Projection System (2001).

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	**1.7**	**1.5**	**1.6**	**1.8**	**1.9**	**2.0**	**2.1**	**1.3**
United States[a]	1.5	1.3	1.4	1.5	1.6	1.7	1.8	1.3
Canada	0.2	0.2	0.2	0.2	0.2	0.2	0.3	1.1
Mexico	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
Western Europe	**1.0**	**1.0**	**1.0**	**1.1**	**1.1**	**1.1**	**1.1**	**0.3**
United Kingdom	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.4
France	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2
Germany	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Italy	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2
Netherlands	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3
Other Western Europe	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.3
Industrialized Asia	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.5**
Japan	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.4
Australasia	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.8
Total Industrialized	**3.0**	**2.8**	**2.9**	**3.1**	**3.3**	**3.4**	**3.5**	**0.9**
EE/FSU								
Former Soviet Union	0.8	0.5	0.5	0.6	0.6	0.7	0.7	1.4
Eastern Europe	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1.1
Total EE/FSU	**0.8**	**0.6**	**0.6**	**0.7**	**0.7**	**0.8**	**0.8**	**1.3**
Developing Countries								
Developing Asia	**0.9**	**1.0**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**	**1.5**
China	0.3	0.4	0.4	0.4	0.5	0.5	0.5	1.5
India	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1.5
South Korea	0.1	0.2	0.2	0.2	0.2	0.2	0.2	1.5
Other Asia	0.4	0.4	0.4	0.5	0.5	0.6	0.6	1.7
Middle East	**0.2**	**0.3**	**0.3**	**0.3**	**0.4**	**0.4**	**0.4**	**1.6**
Turkey	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
Other Middle East	0.2	0.3	0.3	0.3	0.4	0.4	0.4	1.7
Africa	**0.1**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.3**	**1.2**
Central and South America	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.3**	**0.9**
Brazil	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1.1
Other Central/South America	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.9
Total Developing	**1.5**	**1.8**	**1.8**	**2.0**	**2.1**	**2.3**	**2.4**	**1.4**
Total World	**5.3**	**5.2**	**5.3**	**5.8**	**6.1**	**6.4**	**6.7**	**1.1**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.
Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding.
Sources: **History:** Derived from Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, World Energy Projection System (2001).

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 (2001).

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 2001. The package will allow users to replicate the projections that appear in *IEO2001*. 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 8 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.

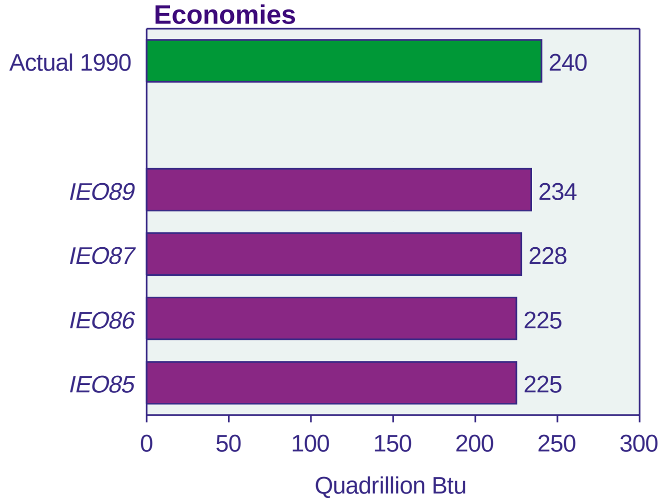
The regional aggregation has changed from report to report. In 1990, the report coverage was expanded for the first time from coverage of only the market economies to coverage of the entire world. Projections for China, the former Soviet Union, and other CPE countries were provided separately.

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, January 2001). **Projections:** EIA, *International Energy Outlook*, DOE/EIA-0484 (Washington, DC, various years).

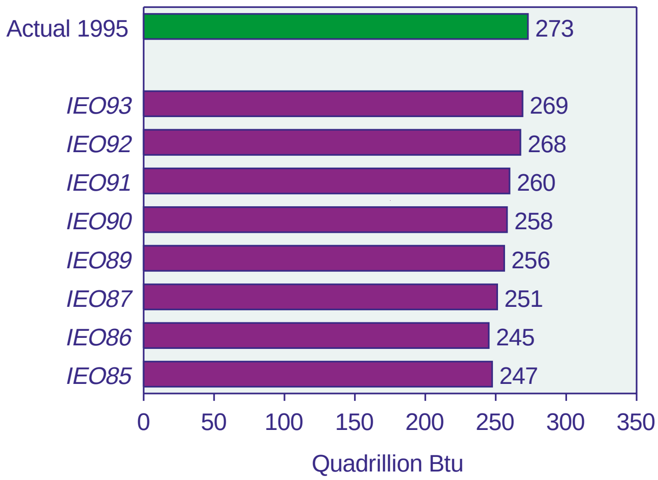
[39]Energy Information Administration, *International Energy Annual 1999*, DOE / EIA-0219(99) (Washington, DC, January 2001).

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.

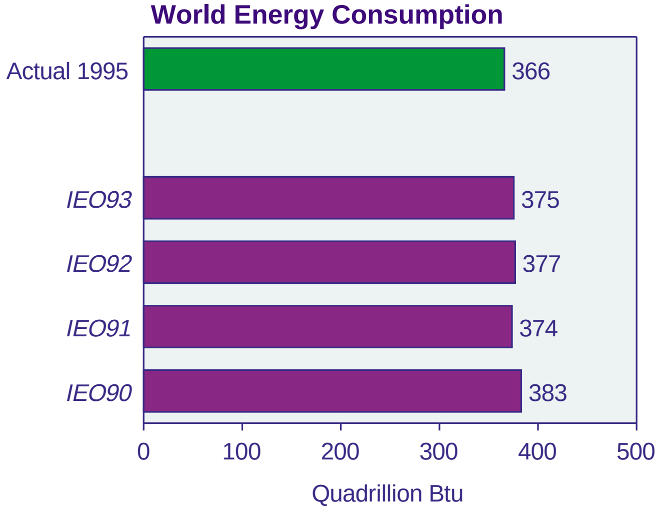
The forecasts for world coal consumption that appeared in the *IEO*s printed between 1990 and 1993 were consistently high, between 4 and 16 percent higher than actual coal use (Figure G6), largely because of overestimates for the former Soviet Union and Eastern Europe—regions that experienced substantial 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



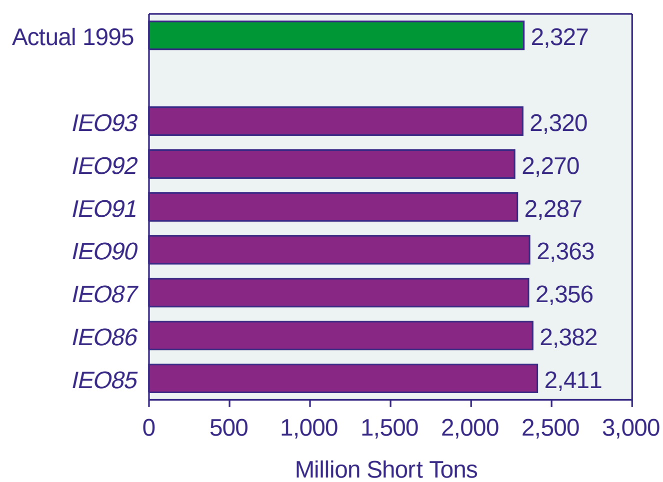
Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, *International Energy Outlook*, DOE/EIA-0484 (Washington, DC, various years).

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, January 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



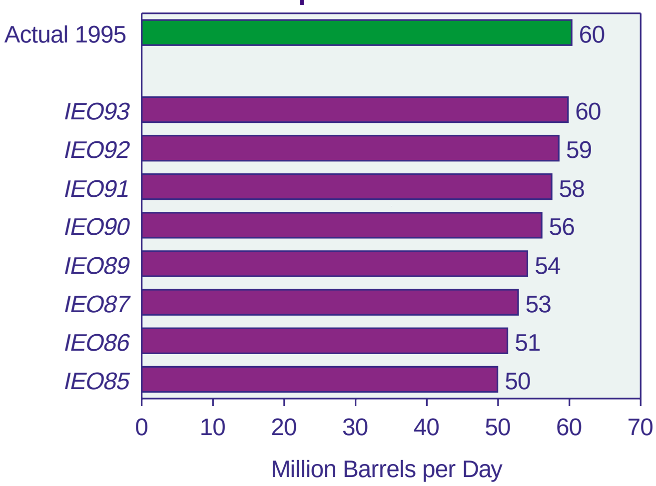
Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, *International Energy Outlook*, DOE/EIA-0484 (Washington, DC, various years).

[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.

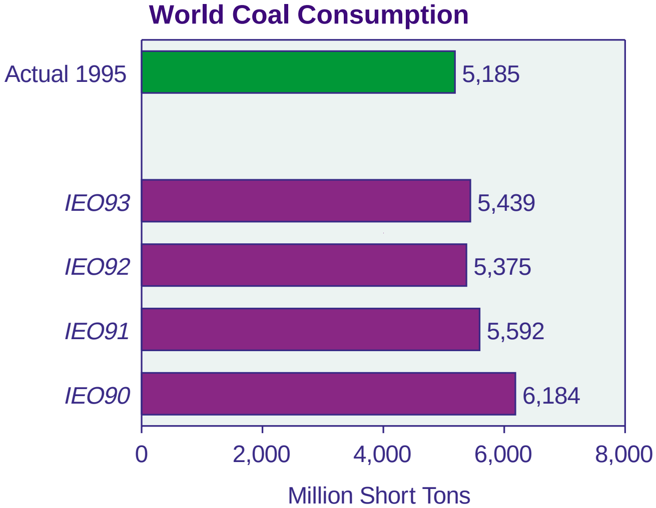
The comparison of *IEO* projections and historical data in the context of political and social events underscores the importance of these events in shaping the world's energy markets. Such comparisons also point out how important a model's assumptions are to the derivation of accurate forecasts. The political and social upheaval in

Figure G5. Comparison of *IEO* Forecasts with 1995 Oil Consumption in Market Economies



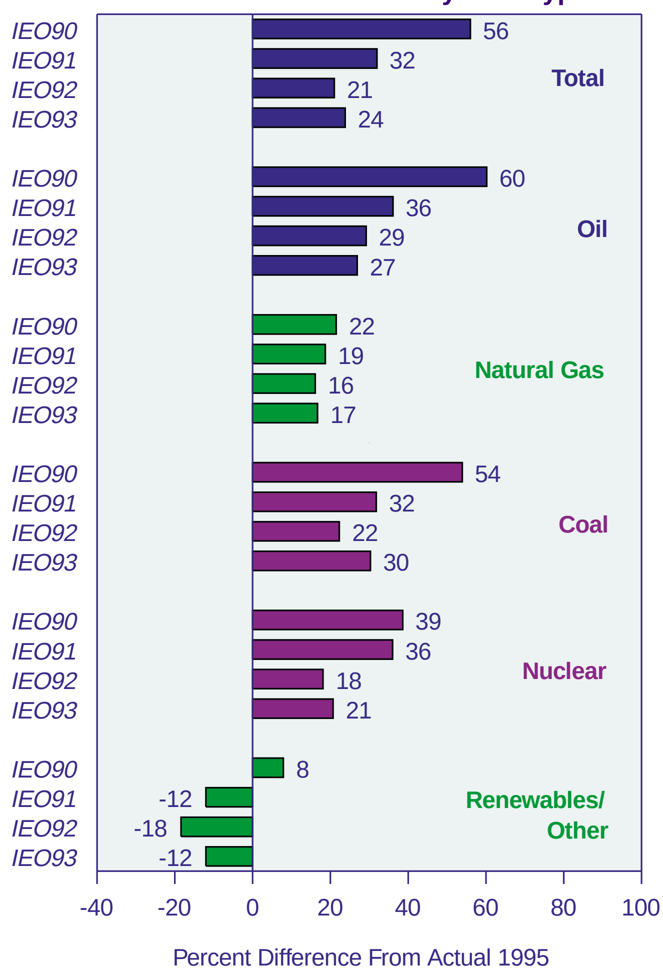
Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, *International Energy Outlook*, DOE/EIA-0484 (Washington, DC, various years).

Figure G6. Comparison of *IEO* Forecasts with 1995 World Coal Consumption



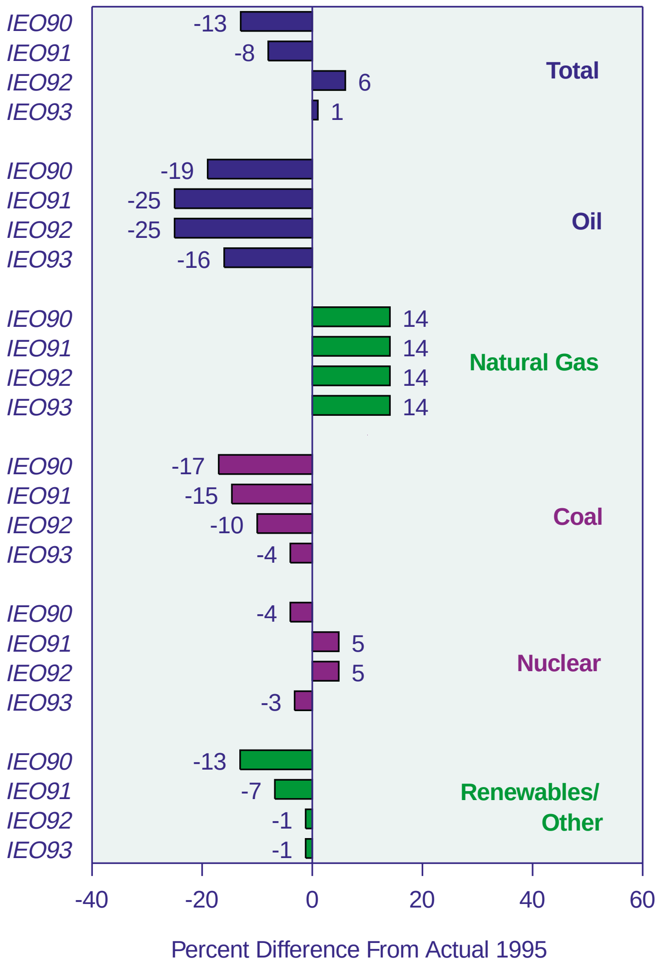
Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, *International Energy Outlook*, DOE/EIA-0484 (Washington, DC, various years).

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, January 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, January 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.