Chapter 5
Electricity

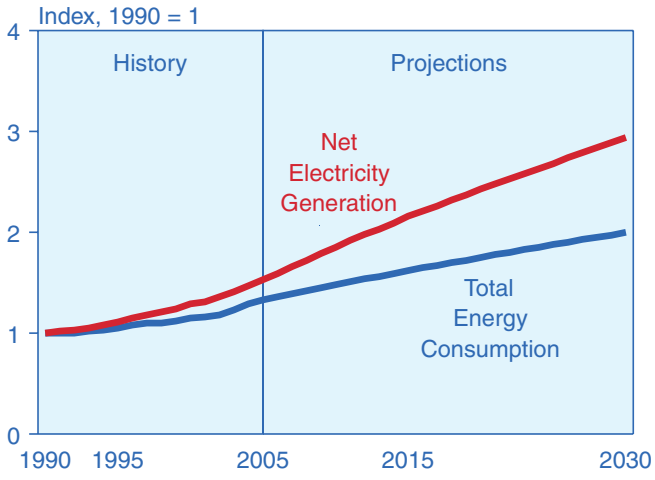
World electricity generation nearly doubles in the IEO2008 reference case from 2005 to 2030. In 2030, generation in the non-OECD countries is projected to exceed generation in the OECD countries by 46 percent.

Over the next 25 years, the world will become increasingly dependent on electricity to meet its energy needs. Electricity is expected to remain the fastest-growing form of end-use energy worldwide through 2030, as it has been over the past several decades. Nearly one-half of the projected increase in energy consumption worldwide from 2005 to 2030 is attributed to electricity generation in the *IEO2008* reference case. Since 1990, growth in net generation has outpaced the growth in total energy consumption (2.9 percent per year and 1.9 percent per year, respectively), and generation is expected to increase at an average annual rate of 2.6 percent through 2030 as the growth in demand for electricity continues to outpace growth in total energy use (Figure 52).

World net electricity generation nearly doubles in the reference case, from 17.3 trillion kilowatthours in 2005 to 24.4 trillion kilowatthours in 2015 and 33.3 trillion kilowatthours in 2030 (Table 10). In general, growth in the OECD countries, where electricity markets are well established and consuming patterns are mature, is slower than in the non-OECD countries, where a large amount of demand remains unsatisfied. The International Energy Agency has estimated that nearly 32 percent of the population in the developing non-OECD countries (excluding non-OECD Europe and Eurasia) do not yet have access to electricity—a total of about 1.6 billion people [*1*]. With the strong economic growth projected for the developing non-OECD nations, substantial increases in electricity generation will be needed to meet demand in the residential, commercial, and industrial sectors.

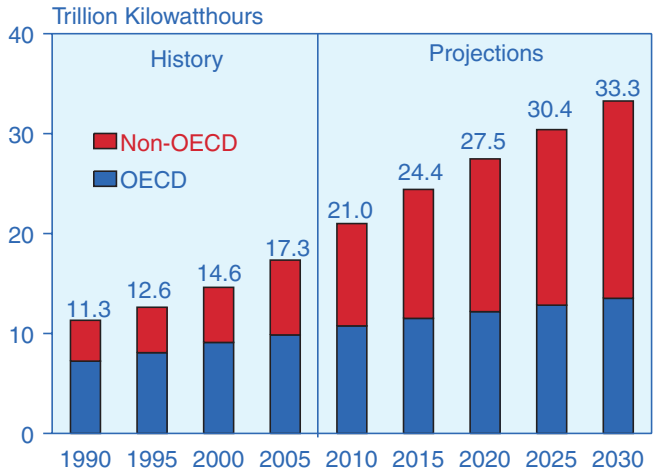
Although the non-OECD nations consumed 24 percent less electricity than the OECD nations in 2005, total non-OECD electricity generation in 2030 is projected to exceed OECD generation by 46 percent (Figure 53). In the developing countries, strong economic growth translates to growing demand for electricity. Increases in per capita income lead to improved standards of living, rising consumer demand for lighting and appliances, and growing requirements for electricity in the industrial sector. As a result, total non-OECD electricity generation increases by an average of 4.0 percent per year in the reference case, as compared with a projected average annual growth rate in OECD electricity generation of 1.3 percent from 2005 to 2030.

Figure 52. Growth in World Electric Power Generation and Total Energy Consumption, 1990-2030



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2005* (June-October 2007), web site www.eia.doe.gov/iea. **Projections:** EIA, World Energy Projections Plus (2008).

Figure 53. World Net Electric Power Generation, 1990-2030



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2005* (June-October 2007), web site www.eia.doe.gov/iea. **Projections:** EIA, System for the Analysis of Global Energy Markets/Global Electricity Module (2008).

Electricity Supply by Energy Source

The mix of primary fuels used to generate electricity has changed a great deal over the past two decades on a worldwide basis. Coal has continued to be the fuel most widely used for electricity generation, although generation from nuclear power increased rapidly from the 1970s through the 1980s, and natural-gas-fired generation grew rapidly in the 1980s and 1990s. The use of oil for electricity generation has been declining since the mid-1970s, when the oil embargo by Arab producers in 1973-1974 and the Iranian Revolution in 1979 produced oil price shocks.

High world oil prices—which have moved upward in every year since 2003—in combination with concerns about the environmental consequences of greenhouse gas emissions are raising renewed interest in nuclear power and renewable energy sources as alternatives to the use of coal and natural gas for electric power generation. Projections of future coal use are particularly sensitive to assumptions about future policies that might be adopted to mitigate greenhouse gas emissions.

Coal

In the *IEO2008* reference case, while natural gas is the fastest-growing energy source for electricity generation worldwide, coal continues to provide the largest share, by a wide margin, of the energy used for electric power production (Figure 54). In 2005, coal-fired generation accounted for 41 percent of world electricity supply; in 2030, its share is projected to be 46 percent. Sustained high prices for oil and natural gas make coal-fired generation more attractive economically, particularly in nations that are rich in coal resources, which include China, India, and the United States. The 3.1-percent projected annual growth rate for coal-fired electricity generation worldwide is exceeded only by the 3.7-percent growth rate projected for natural-gas-fired generation.

The outlook for coal-fired generation could be altered substantially by international agreements to reduce greenhouse gas emissions. The electric power sector offers some of the most cost-effective opportunities for reducing carbon dioxide emissions in many countries. Coal is both the world's most widely used source of

Table 10. OECD and Non-OECD Net Electricty Generation by Fuel, 2005-2030
(Trillion Kilowatthours)

Region	2005	2010	2015	2020	2025	2030	Average Annual Percent Change, 2005-2030
OECD							
Liquids and Other Petroleum	0.4	0.3	0.3	0.2	0.2	0.2	-2.4
Natural Gas	1.9	2.4	2.9	3.2	3.4	3.7	2.6
Coal	3.8	4.0	4.1	4.3	4.5	4.8	1.0
Nuclear	2.2	2.3	2.3	2.4	2.5	2.6	0.6
Renewables	1.5	1.8	1.9	2.0	2.2	2.3	1.6
Total OECD	**9.9**	**10.8**	**11.5**	**12.2**	**12.8**	**13.5**	**1.3**
Non-OECD							
Liquids and Other Petroleum	0.6	0.6	0.6	0.6	0.6	0.6	-0.1
Natural Gas	1.5	2.2	3.0	3.8	4.3	4.7	4.7
Coal	3.4	5.0	6.6	7.8	9.2	10.6	4.7
Nuclear	0.4	0.5	0.7	0.9	1.1	1.2	4.5
Renewables	1.6	1.9	2.0	2.2	2.5	2.7	2.1
Total Non-OECD	**7.5**	**10.2**	**12.9**	**15.3**	**17.6**	**19.7**	**4.0**
World							
Liquids and Other Petroleum	1.0	0.9	0.8	0.8	0.8	0.8	-0.9
Natural Gas	3.4	4.7	5.9	7.0	7.7	8.4	3.7
Coal	7.2	9.0	10.7	12.1	13.7	15.4	3.1
Nuclear	2.6	2.7	3.0	3.3	3.6	3.8	1.4
Renewables	3.2	3.7	3.9	4.2	4.6	5.0	1.8
Total World	**17.3**	**21.0**	**24.4**	**27.5**	**30.4**	**33.3**	**2.6**

Note: Totals may not equal sum of components due to independent rounding.
Sources: **2005:** Derived from Energy Information Administration (EIA), *International Energy Annual 2005* (June-October 2007), web site www. eia.doe.gov/iea. **Projections:** EIA, System for the Analysis of Global Energy Markets/Global Electricity Module (2008).

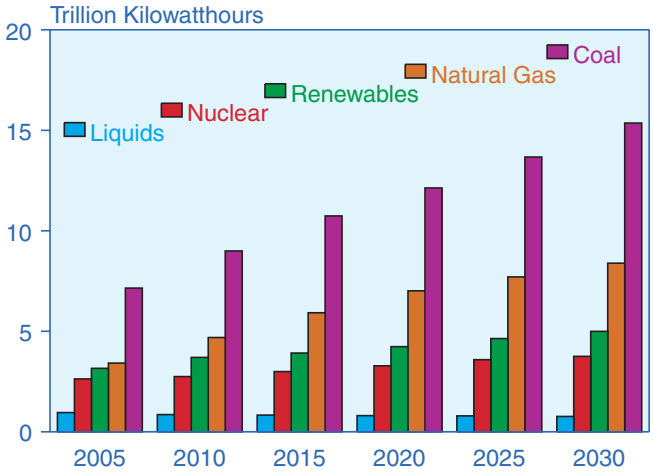
energy for power generation and also the most carbon-intensive energy source. If a cost, either implicit or explicit, were applied to emitters of carbon dioxide, there are several alternative no- or low-emission technologies that currently are commercially proven or under development, which could be used to replace some coal-fired generation. Implementing the technologies would not require expensive, large-scale changes in the power distribution infrastructure or in electricity-using equipment.

It could be more difficult, however, to achieve similar results in the end-use sectors. In the transportation sector, for instance, large-scale reduction of carbon dioxide emissions probably would require extensive changes in the motor vehicle fleet, fueling stations, and fuel distribution systems, at tremendous expense. In contrast, substitution of nuclear power and renewables for fossil fuels in the electric power sector would be a comparatively inexpensive way to reduce emissions, as would improving the efficiency of electric appliances.

Natural Gas

Although natural gas is the fastest-growing energy source for electric power generation in the *IEO2008* reference case projection—increasing from 3.4 trillion kilowatthours in 2005 to 8.4 trillion kilowatthours in 2030—the total amount of electricity generated from natural gas continues to be only about one-half the total for coal, even in 2030. Natural-gas-fired combined-cycle capacity is an attractive choice for new power plants because of its fuel efficiency, operating flexibility (it can be brought on line in minutes rather than the hours it takes for coal-fired and some other generating capacity), relatively short planning and construction times (months instead of the years that nuclear power plants typically require), and capital costs that are lower than those for other technologies.

Figure 54. World Electricity Generation by Fuel, 2005-2030



Sources: **2005:** Derived from Energy Information Administration (EIA), *International Energy Annual 2005* (June-October 2007), web site www.eia.doe.gov/iea. **Projections:** EIA, System for the Analysis of Global Energy Markets/Global Electricity Module (2008).

Liquid Fuels and Other Petroleum

With world oil prices projected to stay relatively high, reaching $113 per barrel (in nominal dollars) at the end of the *IEO2008* projection in 2030, liquids are the only energy source for power generation that is projected to decline on a worldwide basis. As oil prices remain high, nations are expected to reduce or eliminate their use of oil for generation—opting instead for more economical sources of electricity, including coal. Worldwide, generation fueled by liquids is projected to decline by an average of 0.9 percent per year from 2005 to 2030; and in the OECD nations, it is projected to decline by 2.4 percent per year. Only the non-OECD Middle East region, with its ample oil reserves and a current 36-percent share of total electricity generation fueled by oil, is projected to continue relying heavily on oil to meet its electricity needs.

Nuclear Power

Electricity generation from nuclear power is projected to increase from about 2.6 trillion kilowatthours in 2005 to 3.8 trillion kilowatthours in 2030, as concerns about rising fossil fuel prices, energy security, and greenhouse gas emissions support the development of new nuclear generation capacity. High prices for fossil fuels allow nuclear power to become economically competitive with generation from coal, natural gas, and liquids despite the relatively high capital and maintenance costs associated with nuclear power plants. Moreover, higher capacity utilization rates have been reported for many existing nuclear facilities, and it is anticipated that most of the older nuclear power plants in the OECD countries and non-OECD Eurasia will be granted extensions to their operating lives. Still, there is considerable uncertainty associated with nuclear power.

Around the world, nuclear generation is attracting new interest as countries look to increase the diversity of their energy supplies, improve energy security, and provide a low-carbon alternative to fossil fuels. For instance, each of the world's three largest coal-consuming nations (China, the United States, and India) is projected to expand nuclear capacity significantly over the next 25 years (see box on page 64). The nuclear power profile was raised further at the December 2007, United Nations Climate Change Conference in Bali, when International Energy Agency Director Nobuo Tanaka suggested that nuclear power would have to be part of the solution to "stabilize and reduce man-made emissions in the foreseeable future" [2].

Mid-Term Prospects for Nuclear Electricity Generation in China, India, and the United States

Around the world, nuclear power plants are getting renewed attention and consideration as an option for electricity generation to meet rising demand in the future. For many years, analysts expected nuclear power to grow slowly in the short term and decline in the long term. More recently, however, many countries have begun looking anew at nuclear power to displace generation from fossil fuels, in response to both sustained high prices for oil and natural gas and the desire to reduce carbon dioxide emissions. In addition, concerns about energy security among those nations that rely heavily on fossil fuel imports have made nuclear power an attractive option for electricity production.

Still, there are barriers to the nuclear power option, including public concerns about plant safety, disposal of radioactive waste, and nuclear weapons proliferation—not to mention the relatively high capital and maintenance costs of nuclear plants. Even if safety, health, and political concerns were answered sufficiently to allow new nuclear plants to be built, the escalating expense of building them (particularly, in comparison with capital costs for other plant types) could prevent them from being constructed. The costs of commodities such as iron, steel, cement, and concrete, as well as the capital costs of energy equipment and facilities, all have increased substantially in the past few years; and because nuclear plants tend to be more capital intensive than fossil fuel generators, these cost increases tended to make nuclear power less competitive despite the recent surge in fossil fuel prices.

In at least three countries—China, India, and the United States—nuclear power currently is positioned for strong growth (see figure opposite):

- Although China has the youngest nuclear power program of the three nations (its first nuclear power plant began operating in 1991), it is expected to add a net 45 gigawatts of nuclear capacity by 2030. In the *IEO2008* reference case, China's nuclear electricity generation increases from 50 billion kilowatthours in 2005 to 410 billion kilowatthours in 2030, an average annual growth rate of 8.8 percent.
- India is projected to add 17 gigawatts of new nuclear capacity and increase production by 9.4 percent annually. Although India has not signed the international Nuclear Non-Proliferation Treaty (NPT), it is expected to forge an agreement with the United States and the International Atomic Energy Agency (IAEA) that will allow it to import sufficient fuel and reactor parts to achieve the projected increase.
- The United States is projected to add 16.6 gigawatts of new nuclear capacity and 2.7 gigawatts of capacity in the form of uprates to existing plants. Those increases are partially offset, however, by the anticipated retirement of several older reactors.

China

China is trying to diversify its sources of electricity, and increasing nuclear power capacity is seen as a strategy to achieve that goal. Unlike most of the OECD nations, China will be able to expand its nuclear program largely without political deterrents.

At present, China has 11 commercial nuclear power reactors in operation, 6 of which have been brought on line since 2002. Another 6 plants are currently under construction, and several more are in various stages of planning.[a] The Chinese government is also in the process of awarding billions of dollars in contracts to build additional nuclear plants. France's AREVA, Russia's AtomStroyExport, and U.S.-based Westinghouse all have won bids. In the world's largest nuclear power deal to date, China will pay $11.9 billion to AREVA to build two nuclear reactors.

China hopes to construct 30 new reactors by 2020, increasing its nuclear portfolio from 2.3 percent of the

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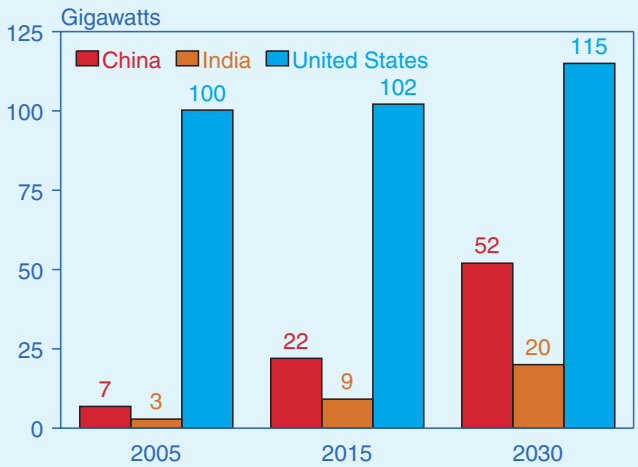
Nuclear Electricity Generation Capacity in China, India, and the United States, 2005, 2015, and 2030



Sources: **2005:** Energy Information Administration (EIA), *International Energy Annual 2005* (June-October 2007), web site www.eia.doe.gov/iea. **2015 and 2030:** EIA, System for the Analysis of Global Energy Markets/Global Electricity Module (2008).

[a]International Atomic Energy Association, "Power Reactor Information System," web site www.iaea.org/programmes/a2/index.html; and "China's Nuclear Power Aspirations," *Energy Biz Insider* (December 12, 2007).

Mid-Term Prospects for Nuclear Electricity Generation in China, India, and the United States (Continued)

country's total electricity generation in 2008 to 6 percent in 2020. By 2050, it aims to have at least 150 gigawatts of installed nuclear capacity, providing 22 percent of the country's projected generation mix.[b] In the *IEO2008* reference case, China's installed nuclear capacity reaches 35 gigawatts in 2020, 45 gigawatts in 2025, and 52 gigawatts in 2030, which would supply 5 percent of its total electricity generation in 2030.

India

India's first nuclear power plant became operational in 1969. Since that time, however, the growth in operating nuclear capacity has been slow and, at best, uneven. In 2005 nuclear power accounted for just 2.4 percent of India's electricity generation, and its operating nuclear capacity totaled only 2.8 gigawatts. Because India has refused to sign the NPT, it has been barred from importing nuclear reactors and fuel from the 45-nation Nuclear Suppliers Group (NSG).

In response to rapid growth in electricity demand, India is intent on increasing its generation from nuclear power. The country's Department of Atomic Energy has a goal of increasing nuclear capacity to 20 gigawatts by 2020, more than seven times the current installed nuclear capacity.[c]

To support such an expansion of its nuclear program, India began talks with the United States in July 2005, in an effort to build favorable conditions that will allow it to purchase nuclear reactor parts and fuel. On the part of the United States, negotiations are aimed at persuading India to agree to some nonproliferation measures that would enable it to import nuclear materials without becoming a full signatory to the NPT. The negotiations are suspended at present because of dissent among members of some of India's political parties, who do not trust the political, economic, and military relationships being developed as part of the strategic partnership between India and the United States. The talks are expected to resume in the near future.[d]

The NSG is awaiting the conclusion of the U.S.-India negotiations, as well as a safeguards agreement between India and the IAEA, before deciding whether to grant India an exception to nuclear import restrictions. Several countries, including France, Russia and Australia, are already discussing nuclear cooperation and contract deals with India in the event that an exception to the NSG guidelines is extended to India.

In the *IEO2008* reference case, India's nuclear power capacity grows rapidly, by an average of 8.2 percent per year, to 14 gigawatts in 2020 and 20 gigawatts in 2030. The projection still falls short, however, of the Indian Prime Minister's goal of achieving 20 gigawatts of operating nuclear generation capacity by 2020.

United States

The United States has the world's oldest commercial nuclear power program. The first electric power generation from nuclear energy occurred on December 20, 1951, in Arco, Idaho; and the world's first large-scale nuclear power plant, a 60-megawatt pressurized-water reactor, began operation on December 2, 1957, in Shippingport, Pennsylvania. The U.S. program expanded quickly in the 1960s and 1970s. Nuclear generation supplied 2.4 percent of U.S. electricity in 1971, 11 percent in 1979, and 20 percent at its height in 1992, when 111 U.S. nuclear generators were in operation. Today, 103 nuclear power plants supply nearly 800 billion kilowatthours of electricity in the United States—just under 20 percent of total U.S. generation.

In the mid- to late 1970s, U.S. public opinion started to turn against nuclear power. The rapidly escalating costs of building nuclear plants, including the costs of added safety measures, throughout the 1970s and 1980s contributed to large increases in electricity prices. Aside from the costs of building and maintaining nuclear plants, the potential dangers of plant malfunctions and the storage of hazardous radioactive wastes were major concerns. In 1978, an accident occurred at the Three Mile Island nuclear plant in central Pennsylvania, when a loss of coolant from the reactor core caused a partial meltdown and some release of radioactivity into the immediate vicinity. No new construction of a nuclear plant has been started since the Three Mile Island accident.

More recently, nuclear energy has increasingly come to be seen as a practical way for the United States to meet rising energy demands while releasing less carbon dioxide into the atmosphere and, simultaneously, increasing energy security. The Energy Policy Act of 2005 (EPACT2005) contained several provisions designed to encourage construction of new nuclear power plants, including a production tax credit of 1.8 cents per kilowatthour for up to 6 gigawatts of new nuclear capacity brought on line before 2021. The credit was authorized for the first 8 years of a plant's

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[b]"China's Nuclear Power Aspirations," *Energy Biz Insider* (December 12, 2007).
[c]World Nuclear Association, "Nuclear Power in India," Information Paper (July 2008), web site www.world-nuclear.org/info/inf53.html.
[d]"India's Nuclear Hopes Hit the Buffers," *Power In Asia*, No. 489 (October 25, 2007), pp. 8-9.

Mid-Term Prospects for Nuclear Electricity Generation in China, India, and the United States (Continued)

operation and up to $125 million for each 1,000-megawatt unit. EPACT2005 also authorized Federal risk insurance for companies building the next six nuclear power plants. In addition, EPACT2005 Title 17 included a provision enabling the Government to guarantee loans for the construction of new energy technologies "that reduce or avoid greenhouse gases," including nuclear power plants. The Secretary of Energy was given the authority, upon choosing a project, to guarantee a loan of up to 80 percent of the project's cost. Such loan guarantees could decrease the costs of nuclear power significantly, by reducing interest rates on the debt and allowing higher debt-to-equity ratios.

By 2010, 23 entities are expected to have submitted combined license applications for the construction of 34 new power plants in the United States.[e] It may, however, take many more years to get plants built in the United States than in either China or India, and any negative (or positive) experiences in those countries could have impacts on U.S. public opinion that would affect efforts to develop new nuclear plants.

In the *IEO2008* reference case, 17 gigawatts of new nuclear capacity is projected to come on line by 2030. The nuclear share of total U.S. electricity generation remains below 20 percent throughout most of the forecast, however, as older nuclear plants are retired and new generators of other types, especially coal-fired, are built.

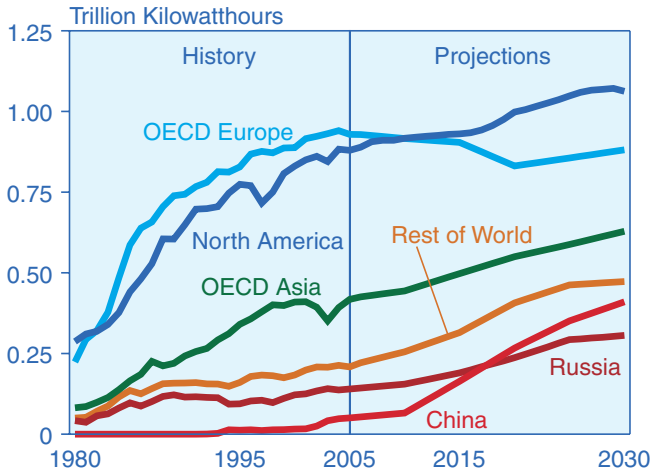
[e]U.S. Nuclear Regulatory Commission, "Expected New Nuclear Power Plant Applications," web site www.nrc.gov/reactors/new-licensing/new-licensing-files/expected-new-rx-applications.pdf (updated July 9, 2008).

Issues that could slow the expansion of nuclear power in the future include plant safety, radioactive waste disposal, and concerns that weapons-grade uranium may be produced from centrifuges installed to enrich uranium for civilian nuclear power programs. These issues continue to raise public concerns in many countries and may hinder the development of new nuclear power reactors. Nevertheless, the *IEO2008* reference case incorporates the improved prospects for world nuclear power. The *IEO2008* projection for nuclear electricity generation in 2025 is 31 percent higher than the projection published in *IEO2003* only 5 years ago.

On a regional basis, the *IEO2008* reference case projects the strongest growth in nuclear power for the countries of non-OECD Asia. For example, in China, electricity generation from nuclear power is projected to grow at an average annual rate of 8.8 percent from 2005 to 2030, and in India it is projected to increase by an average of 9.4 percent per year. Outside Asia, the largest increase in installed nuclear capacity among the non-OECD nations is projected for Russia, where nuclear power generation increases by an average of 3.2 percent per year. In contrast, OECD Europe is expected to see a decline in nuclear power generation as some national governments, including those of Germany and Belgium, still have plans in place to phase out nuclear programs entirely (Figure 55).

To address the uncertainty inherent in projections of nuclear power growth in the long term, a two-step approach was used to formulate the outlook for nuclear power in *IEO2008*. In the mid-term (through 2015), projections are based primarily on the current activities of the nuclear power industry and national governments. Because of the long permitting and construction lead times associated with nuclear power plants, there is general agreement among analysts about the nuclear projects that are likely to become operational in the mid-term. After 2015, the projections are based on a combination of announced plans or goals at the country and regional levels and consideration of other issues facing the development of nuclear power, including economics, geopolitical issues, technology advances, and environmental policies. The availability of potential uranium resources was also considered as part of the *IEO2008* modeling effort. Reserves appear to be more than sufficient to meet the expected growth in nuclear capacity worldwide (see box on page 67).

Figure 55. World Net Electricity Generation from Nuclear Power, 1980-2030



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2005* (June-October 2007), web site www.eia.doe.gov/iea. **2030:** EIA, System for the Analysis of Global Energy Markets/Global Electricity Module (2008).

Hydroelectricity and Other Renewables

In the *IEO2008* reference case, electricity generation from hydroelectric and other renewable energy resources is projected to increase at an average annual rate of 1.8 percent from 2005 to 2030. High prices for oil and natural gas, which are expected to persist in the reference case, also encourage expanded use of renewable fuels. Renewable energy sources are attractive for environmental reasons, especially in countries where reducing greenhouse gas emissions is of particular concern. Government policies and incentives to increase the use of renewable energy sources for electricity generation are expected to encourage the development of renewable energy even when it cannot compete

Uranium Supplies Are Sufficient To Power Reactors Worldwide Through 2030

Current uranium reserves should be adequate to meet additional demand as worldwide installed nuclear capacity increases to the 498 gigawatts in 2030 projected in the *IEO2008* reference case. According to results from the demand model used by the OECD Nuclear Energy Agency and the International Atomic Energy Agency, annual uranium requirements are expected to grow from 68,000 metric tons per year in 2005 to 96,000 metric tons per year in 2030.[a] The cumulative demand for uranium to meet the projected increase in nuclear electricity generation from 2005 to 2030 would be 2.1 million metric tons.[b,c]

Uranium resources are divided into four groups, based on the confidence of supply estimation. *Reasonably assured resources* (RAR) are known uranium deposits that can be recovered with current mining technologies and methods. *Inferred resources* are uranium deposits that are believed to exist, based on direct geological evidence, but have not been studied as thoroughly as RAR. Resources could be expanded even further with *prognosticated resources*—uranium deposits expected to exist on the basis of indirect evidence—and *speculative resources* thought to exist on the basis of geological extrapolations.[d] The table below shows the two groups of worldwide uranium reserves estimated with the highest confidence, at various production cost levels.

Production Cost (Nominal U.S. Dollars per Kilogram of Uranium)	Metric Tons of Uranium Reserves as of January 1, 2005		
	Reasonably Assured	Inferred	Total
Less Than $40	1,947,000	799,000	**2,746,000**
Less Than $80	2,643,000	1,161,000	**3,804,000**
Less Than $130	3,297,000	1,446,000	**4,743,000**

Even in the lowest cost tier, less than $40 per kilogram, total uranium reserves should be sufficient to meet the requirements for projected nuclear capacity in 2030. In addition, with the spot price of uranium oxide having risen from $14.1 per kilogram in January 2001 to $163.1 per kilogram (equivalent to $192.4 per kilogram of uranium) during the week of March 7, 2008, and expected to remain high, it seems unlikely that production costs will hamper the future supply of uranium.[e]

Assuming that the available uranium resources will be adequate, more uranium production will be needed to ensure the annual delivery of 96,000 metric tons. In recent years, 40 to 50 percent of the world's uranium supply has come from secondary sources, including stockpiles of uranium, reprocessed spent fuel, and re-enriched depleted uranium tails.[f] Those secondary sources are expected to decline over the next 5 years, as the "Megatons to Megawatts" program, which converts decommissioned Russian warheads into commercial fuel, concludes in 2013. Primary production, which provided 40,263 metric tons of uranium in 2004, will have to be increased further to make up for diminishing secondary sources and increasing demand.[g]

The relatively high price of uranium already is leading to increased output. New mines in Australia, Canada, Kazakhstan, Brazil, and India are expected to add 30,000 metric tons of production capacity by 2010.[h] The reference case used by the World Nuclear Association projects the addition of 30,000 metric tons of supply by 2015, before uranium mining slowly decreases to 90 percent of its peak 2015 level in 2030.[i] Also, the uranium supply can be extended further by worldwide recycling of spent fuel and the use of breeder reactors.

[a]International Energy Agency, *World Energy Outlook 2006* (Paris, France, November 2006), p. 377, web site www.iea.org/textbase/nppdf/free/2006/weo2006.pdf.
[b]International Energy Agency, *World Energy Outlook 2006*, p. 379.
[c]Assuming that 4 metric tons of uranium is required to fuel 1 million watts of nuclear capacity.
[d]International Atomic Energy Agency, *Analysis of Uranium Supply to 2050* (Vienna, Austria, May 2001), pp. 2-3, web site www-pub.iaea.org/MTCD/publications/PDF/Pub1104_scr.pdf.
[e]TradeTech Uranium.Info Web Site, "Uranium Spot Price Indicator," web site www.uranium.info.
[f]International Energy Agency, *World Energy Outlook 2006*, p. 377.
[g]International Energy Agency, *World Energy Outlook 2006*, p. 380.
[h]Y. Sokolov, "Uranium Resources: Plenty To Sustain Growth of Nuclear Power," Statements of the Deputy Directors General (Vienna, Austria, June 1, 2006), web site www.iaea.org/NewsCenter/Statements/DDGs/2006/sokolov01062006.html.
[i]World Nuclear Association, *The Global Nuclear Fuel Market: Supply and Demand 2007-2030* (London, UK, 2007), p. 112, web site www.world-nuclear.org/reference/publications.html.

economically with fossil fuels. Nonetheless, the renewable share of world electricity generation falls slightly in the projection, from 18 percent in 2005 to 15 percent in 2030, as growth in the consumption of both coal and natural gas in the electricity generation sector worldwide exceeds the growth in renewable sources of generation. The capital costs of new power plants using renewable fuels remain relatively high in comparison with those for plants fired with coal or natural gas.

There is wide variation in the expectations for renewable energy use among the non-OECD countries. In the developing non-OECD nations of Asia and Central and South America, mid- to large-scale hydroelectric power plants are likely to dominate increases in renewable energy use over the projection period. China, India, and Brazil all have plans to expand hydroelectric capacity to help meet growing electricity demand. In contrast, hydroelectricity is not likely to expand strongly in the Middle East, where few countries have the natural resources needed to power hydroelectric facilities.

Among the OECD nations, hydroelectricity is fairly well established, and there are few plans to install major hydroelectric power projects in the future (with the exception of Canada and Turkey). Most of the growth in renewable electricity in the OECD countries is instead likely to come from nonhydroelectric renewable energy sources, especially wind and biomass. A number of OECD countries have incentives in place to increase the use of nonhydroelectric renewables for power generation, particularly to help stem the growth of greenhouse gas emissions produced by fossil fuel use and to promote energy independence. In the *IEO2008* reference case, OECD renewable generation grows by 1.6 percent per year from 2005 to 2030, second only to the growth rate for natural-gas-fired generation.

The *IEO2008* projections for hydroelectricity and other renewable energy resources include only marketed renewables. Non-marketed (noncommercial) biofuels from plant and animal sources are an important source of energy, particularly in non-OECD economies, and the International Energy Agency has estimated that some 2.5 billion people in developing countries depend on traditional biomass as their main fuel for cooking [3]. Non-marketed fuels and dispersed renewables (renewable energy consumed on the site of production, such as energy from solar panels used to heat water) are not included in the projections, however, because comprehensive data on their use are not available.

Regional Outlook

In the *IEO2008* reference case, the highest projected growth rates for electricity generation are for the non-OECD nations, where strong economic growth and rising personal incomes drive the projected growth in demand for electric power. In the OECD countries, where electric power infrastructures are relatively mature, national populations generally are expected to grow slowly or decline, and GDP growth is expected to be slower than in the developing nations, the increases in demand for electricity are projected to be much slower than those in the non-OECD countries. For example, electricity demand in China is projected to grow by an annual average of 5.4 percent from 2005 to 2030, which is more than five times the rate projected for the United States (Figure 56).

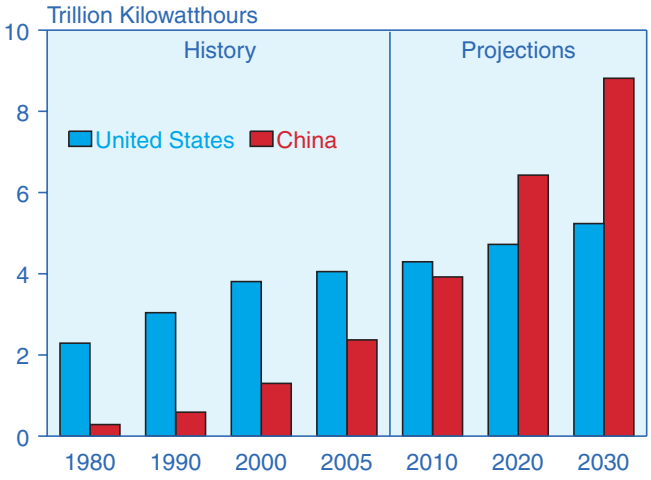
OECD Economies

North America

In 2005, electricity generation in North America totaled 4.9 trillion kilowatthours and accounted for 28 percent of the world's total generation. That share is projected to decline over the course of the projection period, as the non-OECD nations experience fast-paced growth in electric power demand. In 2030, North America accounts for only 20 percent of the world's electric power generation.

The United States is the largest consumer of electricity in North America and is projected to remain in that position through 2030 (Figure 57). U.S. electricity generation—including both generation by electric power producers and on-site generation—is projected to increase slowly, at an average annual rate of 1.0 percent. Canada, like the United States, has a mature electricity market, and its generation is projected to increase by 1.5 percent per year from 2005 to 2030. Mexico's electricity generation grows at a faster rate—averaging 3.3 percent per

Figure 56. Net Electricity Generation in the United States and China, 1980-2030



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2005* (June-October 2007), web site www.eia.doe.gov/iea. **Projections:** EIA, System for the Analysis of Global Energy Markets/Global Electricity Module (2008).

year through 2030—reflecting the relatively undeveloped state of the country's electric power infrastructure.

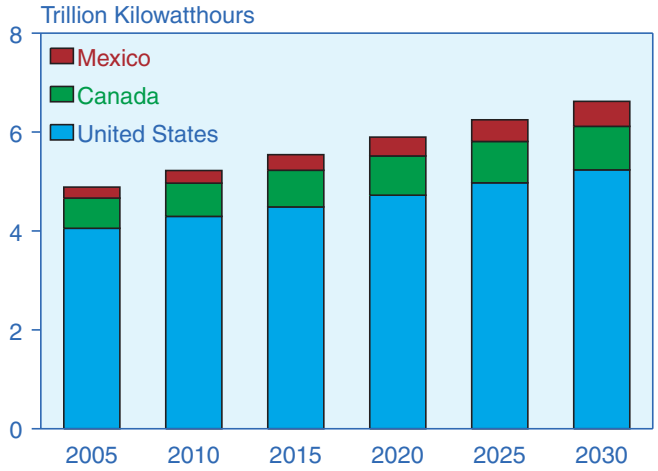
There are large differences in the mix of energy sources used to generate electricity in the three countries that make up OECD North America, and those differences are likely to become more pronounced in the future (Figure 58). In the United States, coal is the leading source of energy for power generation, accounting for 50 percent of the 2005 total; but in Canada, renewable energy sources (predominantly hydroelectricity) provided 60 percent of the nation's electricity generation in 2005. Most of Mexico's electricity generation currently is fueled by petroleum-based liquids and natural gas, which together accounted for 61 percent of its total electricity generation in 2005. In the reference case projections for 2030, U.S. reliance on coal is even greater than it is today; Canada's hydropower resources (along with some generation from wind capacity scheduled to be built) continue to provide nearly 60 percent of its electricity; and the natural gas share of Mexico's total electricity generation increases from 35 percent in 2005 to 71 percent in 2030.

In the United States, much of the growth in electricity generation is projected to be from coal-fired generation and renewables, rather than natural gas. The U.S. natural gas share of electricity generation (including generation in the end-use sectors) remains between 20 percent and 21 percent through 2017, then falls to 14 percent in 2030. The coal share of generation, in contrast, remains just below 50 percent until 2018, then increases to 54 percent in 2030. The rise in U.S. coal-fired generation in the *IEO2008* reference case is explained by a combination of coal prices that remain substantially lower than natural gas prices throughout the projection and the absence of legislation restricting the growth of carbon dioxide emissions. Recent EIA analysis suggests that the enactment of such legislation would lead to significant changes in the projected U.S. generation mix.[14]

Generation from renewable energy sources in the United States increases in the reference case from 0.4 trillion kilowatthours in 2005 to 0.7 trillion kilowatthours in 2030, with much of the growth attributable to nonhydroelectric renewable generation. The use of wind, solar, geothermal, and biomass increases largely as a result of State renewable portfolio standard (RPS) programs, which require that specific and generally increasing shares of electricity sales be supplied by renewable resources. Given that the consumer costs of the RPS programs would increase significantly if Federal production tax credits expired, past projections gave more weight to the probability that generators would exercise so-called "escape clauses" and opt out of the programs. *IEO2008* assumes that, in the absence of a clear indication to the contrary, State RPS goals will be met and result in substantial additional growth of generation from wind, biomass, and geothermal resources.

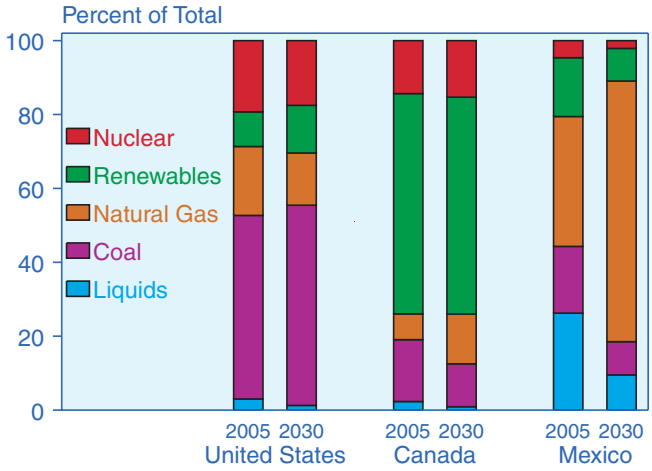
The United States is expected to add 14.6 gigawatts of net nuclear installed capacity between 2005 and 2030.

Figure 57. Net Electricity Generation in OECD North America, 2005-2030



Sources: **2005:** Energy Information Administration (EIA), *International Energy Annual 2005* (June-October 2007), web site www.eia.doe.gov/iea. **Projections:** EIA, System for the Analysis of Global Energy Markets/Global Electricity Module (2008).

Figure 58. Net Electricity Generation in OECD North America by Fuel, 2005 and 2030



Sources: **2005:** Derived from Energy Information Administration (EIA), *International Energy Annual 2005* (June-October 2007), web site www.eia.doe.gov/iea. **2030:** EIA, System for the Analysis of Global Energy Markets/Global Electricity Module (2008).

[14]See Energy Information Administration, *Energy Market and Economic Impacts of S. 2191, the Lieberman-Warner Climate Security Act of 2007*, SR-OIAF/2008- 01 (Washington, DC, April 2008); and *Energy Market and Economic Impacts of S. 1766, the Low Carbon Economy Act of 2007*, SR-OIAF/2007-06 (Washington, DC, January 2008), web site www.eia.doe.gov/ oiaf/service_rpts.htm.

The increase includes 16.6 gigawatts of newly built nuclear facilities and 2.7 gigawatts of uprates at existing nuclear power plants. The additional nuclear power capacity is offset, in part, by the retirement of 4.5 gigawatts of capacity at older nuclear power plants.

In Canada, generation from natural gas is projected to increase, while coal-fired generation remains flat and oil-fired generation declines. The Province of Ontario had announced plans to close all its coal-fired plants by the end of 2007 because of health and environmental concerns, but that date has since been pushed back to 2014. In 2007, the Ontario Power Authority—responsible for ensuring an adequate supply of electric power—filed a 20-year, $60 billion plan (U.S. dollars) for the Province's electricity system, including the phaseout of coal-fired capacity [***4***]. In the reference case, those retirements are offset by increases elsewhere in the country—notably, Alberta and Nova Scotia. As a result, Canada's coal-fired generation remains flat through 2030, at about 0.1 trillion kilowatthours. Increases in Canada's total electricity generation are fueled instead by natural gas (increasing by 4.2 percent per year), nuclear power (1.7 percent per year), and hydroelectricity and other renewables (1.4 percent per year).

Hydroelectricity remains a key source of electricity for Canada. In 2005, the hydroelectric share of total generation in Canada was 59 percent. In addition, several large- and small-scale hydroelectric facilities currently are either planned or under construction in Canada. Hydro-Québec has announced plans to construct a 768-megawatt powerhouse near Eastman and a smaller 120-megawatt facility at Sarcelle in Québec, both of which are expected to be fully commissioned by 2012 [***5***]. Other planned hydroelectric projects include the 2,260-megawatt Lower Churchill River project in Newfoundland and Labrador, the 1,550-megawatt Romaine River project in Québec, and the 200-megawatt Wuskwatim project in Manitoba [***6***]. The *IEO2008* reference case does not anticipate that all planned projects will be constructed, but given Canada's historical experience with hydropower and the commitments for construction, new hydroelectric capacity accounts for more than one-half of the 29,600 megawatts of additional renewable capacity projected to be added in Canada between 2005 and 2030.

Although hydropower plays a major role in Canada's renewable electricity generation, the country also has plans to expand wind-powered generating capacity in the future. In 2007, 386 megawatts of installed wind capacity was added, bringing the total to 1,846 megawatts and giving Canada the world's eleventh-largest national installed wind capacity [***7***]. In January 2007, Natural Resources Canada announced its new "ecoENERGY for Renewable Power" program as a follow-up to its Wind Power Production Incentive (WPPI).[15] The new program will allow an additional 3,000 megawatts of wind power to be installed by 2011 [***8***].

In addition to the incentive programs of Canada's federal government, several provincial governments have instituted their own incentives to support the construction of new wind capacity. Ontario's Renewable Energy Standard Offer Program has helped support robust growth in wind installations over the past several years, and installed wind capacity in the province has risen from 0.6 megawatts in 1995 to more than 490 megawatts in 2006 and hit the 500-megawatt milestone in January 2008 [***9***]. The Standard Offer Program pays all small renewable energy generators (with installed capacity less than 10 megawatts) 11.0 cents (Canadian) per kilowatthour of electricity delivered to local electricity distributors [***10***] and 42.0 cents per kilowatthour for electricity from solar photovoltaic projects. Contracts between Ontario Power Authority and the small renewable generators last for a term of 20 years, and beginning in 2007 a portion of the rate paid to generators was to be indexed annually for inflation. Support from Canada's federal and provincial governments—along with sustained higher world oil prices—is expected to support the projected increase in the country's use of wind power for electricity generation.

Most of the projected increase in Mexico's electricity generation is fueled by natural gas. At 0.4 trillion kilowatthours, natural-gas-fired generation in 2030 is 5 times the 2005 level. The resulting growth in Mexico's demand for natural gas strongly outpaces its production, leaving the country dependent on pipeline imports from the United States and LNG from other countries. Currently, Mexico has one LNG import terminal operating and a second under construction, in part to fuel the expected growth in electricity demand. Its first LNG facility, Altamira, became operational in 2006 and the second, Costa Azul, is under construction and expected to be on line by the end of 2008 [***11***].

Mexico's electricity generation is projected to increase by an average of 3.3 percent annually from 2005 to 2030—double the rate for Canada and triple the rate for the United States—and its government has recognized the need for electricity infrastructure to keep pace with growth in demand. In early 2008, the government announced plans to invest around $3.1 billion in electricity infrastructure in 2008 under the 2007-2012 National Infrastructure Programme [***12***]. As part of a major plan to increase power generation, the state-owned Comisión

[15]The WPPI supports the development of 4,000 megawatts of wind power by 2010, with qualifying wind producers eligible to receive an incentive of $0.01 per kilowatthour (Canadian dollars) for the first 10 years of production from new installations.

Federal de Electricidad (CFE) expects to begin construction in 2009 on a 652-megawatt natural-gas-fired combined-cycle power plant, Norte II in Chihuahua, with a completion target of 2011 [***13***]. The CFE has announced plans to add more than 26 gigawatts of new installed electric power capacity by 2017.

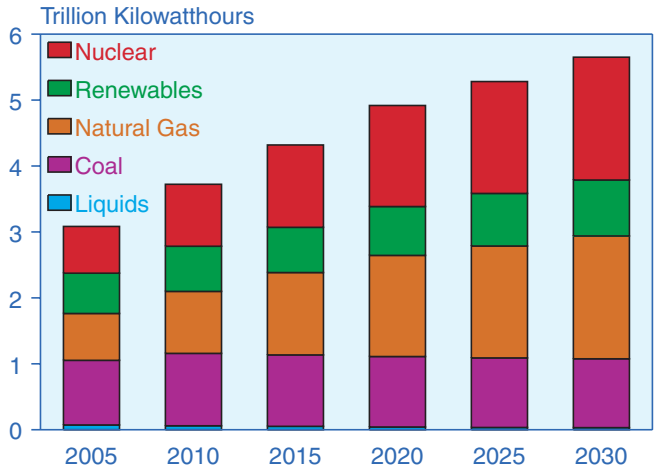
OECD Europe

Electricity generation in the nations of OECD Europe increases by an average of 1.4 percent per year in the *IEO2008* reference case, from 3.3 trillion kilowatthours in 2005 to 4.0 trillion kilowatthours in 2015 and 4.7 trillion kilowatthours in 2030. Because most of the OECD Europe countries have relatively stable populations and mature electricity markets, most of the growth in electricity demand is projected to come from those with more robust population growth (including Turkey, Ireland, and Spain) and from the newest OECD members (including the Czech Republic, Hungary, and Poland), whose economic growth rates exceed the OECD average through the projection period.

Natural gas is expected to be by far the fastest-growing fuel for electricity generation in OECD Europe, increasing at an average rate of 3.9 percent per year from 2005 to 2030. Use of liquids and other petroleum for generation is projected to decline steadily in the face of rising world oil prices (Figure 59).

OECD Europe's total nuclear capacity declines from 133 gigawatts in 2005 to 114 gigawatts in 2020 in the reference case, followed by a modest net increase to 118 gigawatts in 2030. Belgium and Germany, with substantial nuclear programs, have policies in effect to reduce their use of nuclear power in the future; however, it is unclear whether the planned nuclear plant closures will actually take place, given that nuclear power plants produce no carbon dioxide emissions. As a result, the reference case projects more license extensions and fewer retirements of operating nuclear power plants than were expected in earlier assessments, as well as some new builds (about 18 gigawatts of new nuclear capacity) in France, Finland, and possibly other countries of OECD Europe.

Figure 59. Net Electricity Generation in OECD Europe by Fuel, 2005-2030



Sources: **2005:** Derived from Energy Information Administration (EIA), *International Energy Annual 2005* (June-October 2007), web site www.eia.doe.gov/iea. **Projections:** EIA, System for the Analysis of Global Energy Markets/Global Electricity Module (2008).

Coal accounts for nearly one-third of OECD Europe's net generation today, but concerns about carbon dioxide emissions and global warming could reduce that share in the future. On the other hand, in countries that rely heavily on coal for their electricity supplies (including Germany, where coal provides about 55 percent of total generation, and Poland, where it provides 95 percent) it will be difficult to reduce coal use substantially and, at the same time, carry out plans to dismantle nuclear power programs [***14***]. As a result, the *IEO2008* reference case projects that coal-fired electricity generation in OECD Europe will grow at the relatively slow average rate of 0.3 percent per year from 2005 to 2030.

Renewable energy is OECD Europe's second fastest-growing source for electricity generation in the reference case. The use of renewables (primarily nonhydropower) for electricity generation is projected to grow by 1.3 percent per year through 2030. Although most of the economically feasible hydroelectric resources in Europe already have been developed, the countries of OECD Europe have installed substantial amounts of alternative renewable energy capacity—consisting mainly of wind turbines—over the past several years. At present, 7 of the world's 10 largest markets for wind-powered electricity generation are in Europe,[16] and the 27-member European Union accounted for 60 percent of the world's total installed wind capacity at the end of 2007 [***15***]. With many European countries setting new goals to increase nonhydropower renewable electricity generation, the role of wind power in meeting OECD Europe's electricity demand is likely to grow in the future.

OECD Asia

Total electricity generation in OECD Asia is projected to increase by 1.2 percent per year on average, from 1.7 trillion kilowatthours in 2005 to 2.2 trillion kilowatthours in 2030. Japan accounts for the largest share of electricity generation in the region today and continues to do so in the mid-term projection, despite its having the slowest-growing electricity market in the region. Japan's electricity generation increases at a 0.6-percent average annual rate in the *IEO2008* reference case, as compared with

[16] According to the European Wind Energy Association, at the end of 2007 the 10 countries with the largest amounts of installed wind capacity were Germany, the United States, Spain, India, China, Denmark, Italy, France, the United Kingdom, and Portugal.

projected rates of 1.4 percent per year in Australia/New Zealand and 2.3 percent per year in South Korea (Figure 60). Japan's electricity markets are well established, and its aging population and relatively slow projected economic growth in the mid-term translate into slow growth in demand for electric power. In contrast, both Australia/New Zealand and South Korea are expected to have more robust income and population growth, leading to more rapid growth in demand for electricity.

The fuel mix for electricity generation varies widely among the three economies that make up the OECD Asia region. In Japan, natural gas, coal, and nuclear power make up the bulk of the current electric power mix, with natural gas and nuclear accounting for about 53 percent of total generation and coal another 30 percent. The remaining portion is split between renewables and petroleum-based liquids. In 2030, Japan is projected to rely on natural gas, nuclear power, and coal for nearly 90 percent of its electric power supply, with coal's share declining to 23 percent as both natural gas and nuclear power displace its use.

Australia and New Zealand, with their rich coal resources, rely on coal for nearly three-fourths of their combined electricity generation. The remainder is supplied by natural gas and renewable energy sources—largely hydroelectricity. The Australia/New Zealand region uses negligible amounts of oil for electricity generation and no nuclear power, and that is not expected to change over the projection period. Natural-gas-fired generation is expected to grow strongly in the region, at 3.1 percent per year between 2005 and 2030, and that growth will reduce the coal share to 68 percent at the end of the projection.

In South Korea, coal and nuclear power currently provide 41 percent and 38 percent of total electricity generation, respectively. Natural-gas-fired generation grows quickly in the reference case projection, helping to diversify the country's fuel mix. As a result, South Korea's natural gas share of generation reaches 22 percent in 2030, up from 15 percent in 2005. Coal and nuclear power continue to provide most of the country's electricity generation, however, with each providing between 36 and 37 percent of total electricity in 2030.

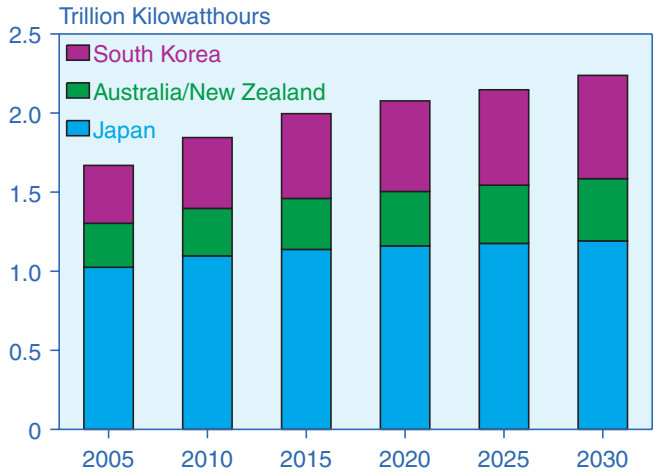
Non-OECD Economies

Non-OECD Europe and Eurasia

Total electricity generation in non-OECD Europe and Eurasia grows at an average rate of 2.6 percent per year in the *IEO2008* reference case, from 1.5 trillion kilowatthours in 2005 to 2.1 trillion kilowatthours in 2015 and 2.8 trillion kilowatthours in 2030. Russia, with the largest economy in non-OECD Europe and Eurasia, accounted for 60 percent of the region's total generation in 2005 and is expected to retain that share throughout the projection (Figure 61).

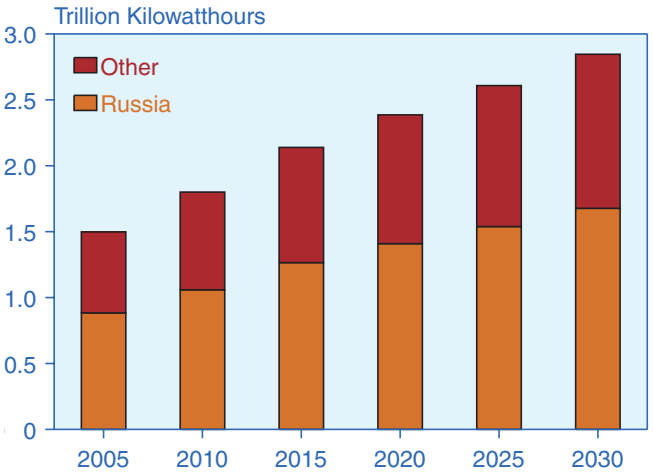
As a whole, non-OECD Europe and Eurasia has ample resources of natural gas. Consequently, much of its future electricity supply is expected to be provided from natural-gas-fired power plants. Natural gas is the region's fastest-growing source of electric power in the *IEO2008* reference case, increasing by 3.5 percent per year from 2005 to 2030. Coal-fired and nuclear power plants also are important regional sources of electricity generation, with projected annual increases averaging 2.7 percent and 2.5 percent, respectively, over the same period. Renewable generation, largely from

Figure 60. Net Electricity Generation in OECD Asia, 2005-2030



Sources: **2005:** Energy Information Administration (EIA), *International Energy Annual 2005* (June-October 2007), web site www.eia.doe.gov/iea. **Projections:** EIA, System for the Analysis of Global Energy Markets/Global Electricity Module (2008).

Figure 61. Net Electricity Generation in Non-OECD Europe and Eurasia, 2005-2030



Sources: **2005:** Energy Information Administration (EIA), *International Energy Annual 2005* (June-October 2007), web site www.eia.doe.gov/iea. **Projections:** EIA, System for the Analysis of Global Energy Markets/Global Electricity Module (2008).

hydropower facilities, increases more slowly, at an average rate of 1.1 percent per year, largely as a result of repairs and expansions at existing sites. Liquids play only a minor role in the electric power markets of non-OECD Europe and Eurasia, and given the expectation that world oil prices will remain relatively high, the role of liquids and other petroleum in the electricity sector remains small.

For Russia, the two fastest-growing energy sources for electric power in the mid-term projection are natural gas and nuclear power. Both are expected to grow by an average of 3.2 percent per year from 2005 to 2030. With its extensive natural gas reserves, Russia currently generates nearly 40 percent of its electricity from natural gas, and the share increases to 46 percent in 2030.

Russia's government also has announced ambitious plans to increase the country's nuclear power capacity in order to lessen the reliance of its power sector on natural gas and preserve what is becoming one of its most valuable export commodities. Although only 3 gigawatts of new nuclear generating capacity has become operational in Russia since 1991, there are plans in place to raise the nuclear share of total generation from about 15 percent currently to 25 percent by 2030 [***16***].

In 2007, Russia announced its intention to construct 26 new nuclear power facilities [***17***]. The government also is in the midst of liberalizing its electricity markets, with complete price liberalization to be phased in by 2011 [***18***]. Russia believes that it must attract private investment in the electric power sector, which could be facilitated by privatization of its generating business. In the short run, however, privatization may slow nuclear expansion plans, given the high capital costs associated with nuclear power plant construction.

The *IEO2008* reference case takes a more conservative view of the rate at which new nuclear power plants will come on line in Russia, and the outlook includes some delay in meeting the current construction schedule. A net total of 4 gigawatts of nuclear generating capacity is added to Russia's existing 23 gigawatts by 2015 and another 14 gigawatts by 2030.

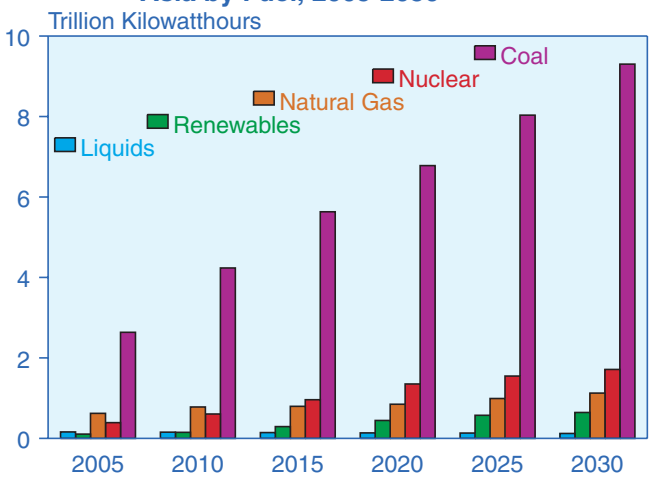
Non-OECD Asia

Non-OECD Asia—led by China and India—has the fastest projected growth in electric power generation worldwide, averaging 4.9 percent per year from 2005 to 2030 in the reference case. The nations of non-OECD Asia are expected to see continued robust economic growth, with corresponding increases in demand for electricity in the building sector, as well as for industrial sector uses. Total electricity generation in non-OECD Asia doubles over the first decade of the projection, from 3.9 trillion kilowatthours in 2005 to 7.8 trillion kilowatthours in 2015, with the region expected to see income growth averaging 7.4 percent per year. The rate of GDP expansion is expected to moderate in the later years of the projection, and the growth in electricity demand slows in concert with income growth. In 2030, total net generation in non-OECD Asia is 12.9 trillion kilowatthours in the reference case.

Coal accounts for two-thirds of the electricity generation in non-OECD Asia (Figure 62)—dominated by generation in China and India. Both countries already rely heavily on coal to produce electric power. In 2005, coal's share of generation was an estimated 77 percent in China and 74 percent in India. Despite efforts to diversify the fuel mix away from coal, it is likely that both countries will continue to use coal as the main fuel for electricity generation. In the *IEO2008* reference case, the coal share of electricity generation declines to 65 percent in 2030 in India but continues rising to 84 percent in China.

In both China and India, meeting future demand for electricity will present challenges. In China, a coal shortage and price spike that began in fall 2007 and continued into 2008 caused 6 gigawatts of coal-fired generating capacity to be taken out of service in southern China [***19***]. An additional 70 gigawatts of coal-fired capacity was idled in February 2008, when severe winter weather disrupted coal deliveries from China's northern mines to coastal demand centers, removing a substantial amount of the country's 440 gigawatts of capacity from service. India also faces supply issues. Coal inventories at the country's utilities have been so low in 2008 that the government has ordered a two-thirds increase in coal imports to assure adequate power supply. Moreover, the coal supply problems in China and India have been

Figure 62. Net Electricity Generation in Non-OECD Asia by Fuel, 2005-2030



Sources: **2005:** Derived from Energy Information Administration (EIA), *International Energy Annual 2005* (June-October 2007), web site www.eia.doe.gov/iea. **Projections:** EIA, System for the Analysis of Global Energy Markets/Global Electricity Module (2008).

exacerbated by coal production problems in Australia and South Africa, cutting available imports [*20*].

Throughout non-OECD Asia, consumption of liquids and other petroleum for electricity generation is projected to decline, as relatively high world oil prices make other fuels more attractive economically. Although the liquids share of electricity generation in non-OECD Asia is projected to fall from 4 percent in 2005 to less than 1 percent in 2030, some oil-fired generation is expected to continue to be needed. Many rural areas currently do not have access to transmission lines, and until transmission infrastructure can be put in place, noncommercial energy sources are expected to be replaced with electricity from diesel-fired generators.

Non-OECD Asia leads the world in installing new nuclear capacity in the *IEO2008* reference case, accounting for 55 percent of the projected net increment in nuclear capacity worldwide. China is projected to add 45 gigawatts of nuclear capacity by 2030, India 17 gigawatts, and the other countries of non-OECD Asia a combined 6 gigawatts. Strong growth of nuclear capacity in China and India will have only a modest impact on fuel diversification in their electric power sectors, however, with thermal generation continuing to dominate in both countries. In China, the nuclear share of total electricity generation is projected to rise from 2 percent in 2005 to 5 percent in 2030, and in India it is projected to rise from 2 percent to 8 percent. Several other countries in the region are also expected to begin nuclear power programs. In the reference case, Vietnam, Indonesia, and Pakistan are projected to have some nuclear power capacity installed by 2030.

Although electricity generation from renewable energy sources in non-OECD Asia is projected to grow at an average annual rate of 2.4 percent, the renewable share of total generation declines—from 16 percent in 2005 to 9 percent in 2030—as the shares of fossil fuels and nuclear power increase more rapidly. Mid- to large-scale hydroelectric facilities provide much of the incremental growth in non-OECD Asia's renewable energy consumption. Several countries have hydropower facilities either planned or under construction: Vietnam is planning a number of hydropower projects on its Vu Gai-Thu Bon River, beginning with the 156-megawatt Song Bung 4 project, which is scheduled for completion by 2011 [*21*]. Malaysia expects to complete the 2,400-megawatt Bakun Dam project by 2011, although the project has had a number of delays and setbacks in the past [*22*].

In India, Himachal Pradesh has plans to commercialize a substantial portion of the state's reported 21,000 megawatts of hydroelectric power potential, adding 5,744 megawatts of hydroelectric capacity before 2015 to the existing 6,300 megawatts [*23*]. Also, the 2,000-megawatt lower Subansiri facility under construction in Arunachal Pradesh is expected to be completed by 2012 [*24*]. India's federal government is attempting to incentivize the development of hydropower across the nation. Legislation has been proposed to allow private hydroelectric power developers to be eligible over a 5-year period for a tariff that would guarantee a fixed return on investment, as well as allowing generators to improve their returns by selling up to 40 percent of their electricity on the spot market.

China also has a number of large-scale hydroelectric projects under construction, including the 18,200-megawatt Three Gorges Dam project slated for completion at the end of 2008. The China Yangtze River Three Gorges Project Development Corporation already has announced it plans to increase its total installed capacity to 22,400 megawatts. In addition, work continues on the 12,600-megawatt Xiluodu project on the Jisha River (scheduled for completion in 2020 as part of a 14-facility hydropower development plan) and the country's third-largest hydroelectric facility, the 6,300 megawatt Longtan project on the Hongshui River [*25*]. China also has the world's tallest dam (at nearly 985 feet) currently under construction, as part of the 3,600-megawatt Jinping I project on the Yalong River, which is scheduled for completion in 2014 as part of a plan by the Ertan Hydropower Development Company to construct 21 facilities with 34,620 megawatts of hydroelectric capacity on the Yalong [*26*]. The China Power Investment Corporation began construction on the first of a proposed 13-dam hydroelectric power system on the Yellow River in 2007, with an ultimate total installed capacity of 8,000 megawatts. The first part of the system, the 360-megawatt Banduo project, is scheduled to become operational by 2011 [*27*].

Although hydroelectric projects dominate the renewable energy mix in non-OECD Asia, there are also plans to increase the use of nonhydroelectric renewable energy sources, especially wind. In China, for example, the National Development and Reform Commission has announced its goal to install 10,000 megawatts of wind power capacity by 2010 [*28*]. The country is well on the way to meet the goal, having installed 3,400 megawatts of new wind capacity in 2007 alone, which brought total installed wind capacity to 6,000 megawatts [*29*]. India's wind capacity has increased steadily over the years, to 8,000 megawatts in 2007. Taiwan also added 100 megawatts of new wind capacity in 2007, bringing its total installed capacity to 282 megawatts.

Middle East

Electric power generation in the Middle East region is projected to grow by 2.6 percent per year, from 0.6 trillion kilowatthours in 2005 to 1.1 trillion kilowatthours in 2030. The region's young and fast-growing population

and a strong rise in projected national income are expected to result in a rapid increase in demand for electric power. In Iran, for instance, electricity demand has been increasing by about 7 percent annually in recent years, and the demand for energy to fuel the increase in electric power generation has pressured the country's supply infrastructure. At the beginning of 2008, unusually cold winter weather increased the demand for natural gas, both for power generation and for residential and commercial uses [***30***]. The sharp increase in natural gas demand has, since 2006, resulted in large natural gas shortages at Iran's power plants during the winter, and many have switched to burning fuel oil and diesel to meet the power demand.

Despite short-term supply issues in some Middle Eastern countries, natural gas is expected to remain the region's largest source of energy for electricity generation throughout the projection (Figure 63). In 2005, natural-gas-fired generation accounted for 56 percent of the Middle East region's total power supply. In 2030, the natural gas share is projected to be 65 percent, as the petroleum share of generation falls over the projection period. Petroleum is a valuable export commodity for many nations of the Middle East, and there is increasing interest in the use of domestic natural gas for electricity generation in order to make more oil assets available for export.

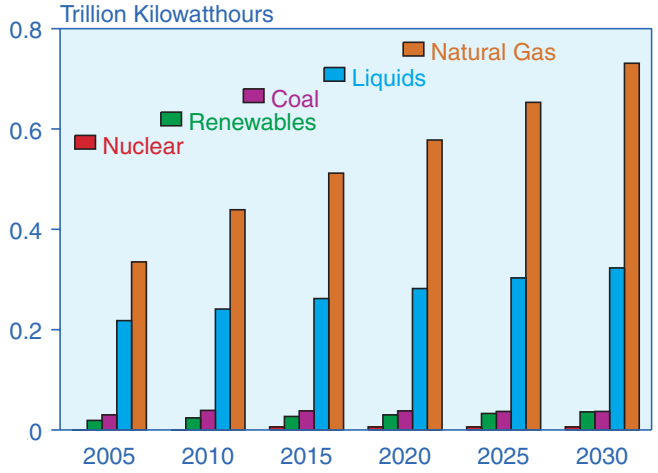
The Middle East is the only region in the world where petroleum liquids are expected to continue accounting for a sizable portion of the fuel mix for electricity generation. The Middle East region as a whole relied on oil-fired capacity to meet 36 percent of its total generation needs in 2005, and petroleum liquids are projected to continue providing 29 percent of the total in 2030. The rich petroleum resources in the Middle East are expected to allow nations of the region to continue using oil for electricity generation, even as high world oil prices result in the displacement of oil in other regions. Oil-fired generation in the Middle East is projected to increase by an average of 1.6 percent per year from 2005 to 2030.

Other energy sources make only minor contributions to the Middle East region's electricity supply. Israel is the only country in the region that uses significant amounts of coal to generate electric power [***31***], and Iran is the only one projected to add nuclear capacity, with the completion of its Bushehr 1 reactor expected by 2015. Finally, because there is little incentive for countries in the Middle East to increase their use of renewable energy sources, renewables are projected to account for a modest 3 percent of the region's total electricity generation throughout the 2005 to 2030 period.

Africa

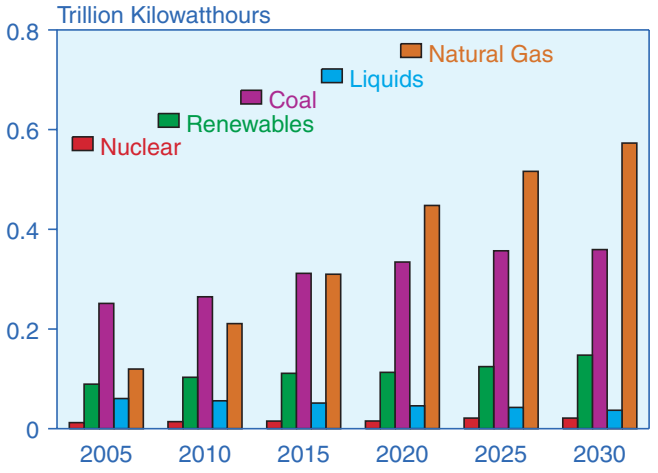
Demand for electricity in Africa grows at an average annual rate of 3.1 percent in the *IEO2008* reference case. Thermal generation accounted for most of the region's total electricity supply in 2005 and is expected to be in the same position through 2030. Coal-fired power plants, which were the region's largest source of electricity in 2005, accounting for 47 percent of total generation, are projected to provide a 32-percent share in 2030, as natural-gas-fired generation expands strongly from 22 percent of the total in 2005 to 50 percent in 2030 (Figure 64).

Figure 63. Net Electricity Generation in the Middle East by Fuel, 2005-2030



Sources: **2005:** Derived from Energy Information Administration (EIA), *International Energy Annual 2005* (June-October 2007), web site www.eia.doe.gov/iea. **Projections:** EIA, System for the Analysis of Global Energy Markets/Global Electricity Module (2008).

Figure 64. Net Electricity Generation in Africa by Fuel, 2005-2030



Sources: **2005:** Derived from Energy Information Administration (EIA), *International Energy Annual 2005* (June-October 2007), web site www.eia.doe.gov/iea. **Projections:** EIA, System for the Analysis of Global Energy Markets/Global Electricity Module (2008).

At present, South Africa's two nuclear reactors are the only ones operating in the region, accounting for about 2 percent of Africa's total electricity generation. Reports suggest that construction of a new Pebble Bed Modular Reactor may begin in South Africa in 2009, with an anticipated completion date of 2013; however, the project has had various setbacks since it was originally initiated in 1993, and it is uncertain whether the schedule will be met [*32*]. In addition, Egypt's government has announced plans to add a nuclear power project, with first tenders offered in early 2008 [*33*]. In the reference case, 1,000 megawatts of new nuclear capacity (net) is projected to become operational in Africa over the 2005 to 2030 period, and the nuclear share of the region's total generation remains at 2 percent through the end of the period.

South Africa is Africa's largest electricity generator, producing nearly 43 percent of the region's total electric power in 2005. The country has been an important regional supplier, exporting electricity to neighbors, including Zimbabwe and Swaziland [*34*]. Electricity demand in South Africa has increased strongly in recent years, and the state-owned public utility Eskom has been unable to expand installed capacity to keep up with increasing domestic demand [*35*]. As a result, South Africa experienced a number of power cuts in 2008 that even resulted in the closure of some mining operations, because companies could not guarantee the safety of workers without a secure power supply. Eskom has plans to increase capacity by adding 40,000 megawatts of new installed electric power capacity by 2025, but short-term supply problems are likely to continue to affect the country and other parts of southern Africa for the foreseeable future.

Generation from hydroelectric resources and other marketed renewable energy sources is expected to grow slowly in Africa. As they have in the past, nonmarketed renewables are expected to continue providing energy to Africa's rural areas; however, it is often difficult for African nations to find funding or international support for larger commercial projects. Still, plans for several hydroelectric projects in the region have been advanced recently, and they may help boost supplies of marketed renewable energy in the mid-term. Several (although not all) of the announced projects are expected to be completed by 2030, allowing the region's consumption of marketed renewable energy to grow by 2.0 percent per year from 2005 to 2030. Several small- to-mid-sized hydroelectric facilities are planned for the region, including a 60-megawatt power station on Tanzania's Kagera River, with construction scheduled to begin in 2009 after financing has been secured [*36*].

Central and South America

Electricity generation in Central and South America increases steadily in the *IEO2008* reference case, from 0.9 trillion kilowatthours in 2005 to 1.3 trillion kilowatthours in 2015 and 1.7 trillion kilowatthours in 2030. The nations of Central and South America are expected to experience strong economic growth through 2030, increasing the demand for electrification. The extent to which electricity consumption will be allowed to expand in the future depends on investment in the power sector and improvements in natural gas supply, including both pipeline and LNG supplies.

The electricity markets of some of the larger regional economies have become strained in recent years. With economic growth exceeding historical trends in Brazil and Argentina, among others, demand for electricity has grown sharply. For example, in Brazil, Central and South America's largest economy, GDP has been increasing on average by 4.3 percent per year since 2004, and at the same time electricity demand has risen by an annual average of 5.0 percent [*37*]. The robust increase in economic expansion has fueled strong demand for electricity in the region, testing the limits of the infrastructure. Brazil has had a difficult time securing natural gas supplies. Bolivia has suspended supplies to a 400-megawatt power plant in Cuiaba, and supplies from Argentina have been suspended as a result of Argentina's own natural gas production problems [*38*].

Brazil has made moves to relieve pressures on its electricity markets with plans to import LNG to reduce reliance on neighboring countries for natural gas supplies and to increase hydroelectric generating capacity [*39*]. Plans to increase Brazil's hydroelectric power generation include two plants on the Rio Madeira in Rondonia: the 3,150-megawatt Santo Antonio and the 3,326-megawatt Jirau hydroelectric facilities. The two plants, with completion dates scheduled for the 2012 to 2015 period, are expected to help Brazil meet electricity demand in the mid-term [*40*]. In the *IEO2008* reference case, renewable electricity supply grows by 2.8 percent per year from 2005 to 2030, led by hydroelectric generation as well as a modest increase in generation from other renewable energy sources; however, with natural-gas-fired generation expanding more rapidly, the renewable share of total generation falls from 86 percent in 2005 to 77 percent in 2030 (Figure 65). Natural-gas-fired generation is projected to grow by 7.3 percent per year in Brazil, with the expectation that infrastructure will be improved and supplies from both pipeline and LNG imports secured in the mid-term. The natural gas share of Brazil's total generation increases from 7 percent in 2005 to 17 percent in 2030.

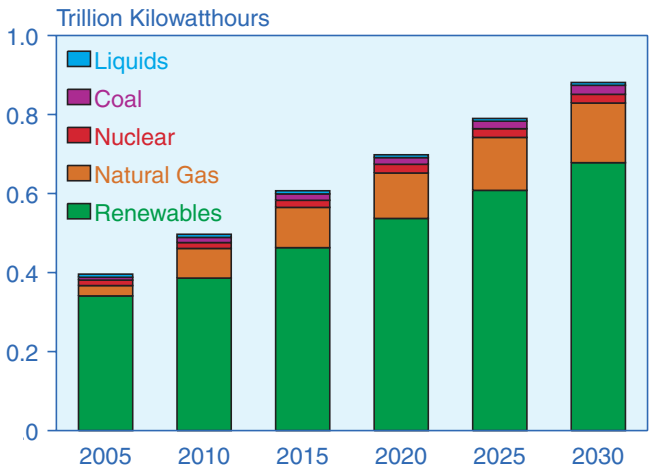
Until recently, Argentina was a major regional supplier of natural gas. In 2003, the government instituted price controls on natural gas to alleviate the impacts of an economic downturn. An unintended result of the price caps was a dramatic downturn in investment in new natural gas projects. Although the Argentine economy

has performed strongly over the past several years, natural gas production and natural-gas-fired generation have not kept pace with the growing demand for electricity. In 2007, Argentina reduced natural gas exports to Chile in the face of rising domestic demand and stagnant production [*41*]. Chile, in turn, has begun construction on an LNG regasification facility at Mejillones, which is scheduled for completion in 2010.

The problems with regional natural gas supplies have been exacerbated by drought conditions that have reduced the ability of nations in Central and South America to meet demand for electric power. Chile's electricity markets, in particular, have been hard-hit by Argentina's supply problems. In addition to coping with reduced supplies, Chile has had very low water levels at its hydroelectric facilities as a result of drought conditions. The Chilean government is pressing consumers to reduce power use by 5 percent but has also announced concerns that—even with such a reduction—electricity rationing may be necessary in the short run [*42*].

Several countries in the region are looking at near-term solutions to meeting electricity demand. Both Argentina and Brazil, for instance, are turning to coal, fuel oil, and diesel generation as emergency alternative sources of power [*43*]. The *IEO2008* projection includes the expectation that coal-fired generation will rise in Central and South America as a result of sustained high prices for oil and natural gas prices. Coal-fired generation increases in Central and South America by 2.6 percent per year on average from 2005 to 2030, but the coal share of generation remains at a modest 6 percent through the end of the projection period.

Figure 65. Net Electricity Generation in Brazil by Fuel, 2005-2030



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