Chapter 5

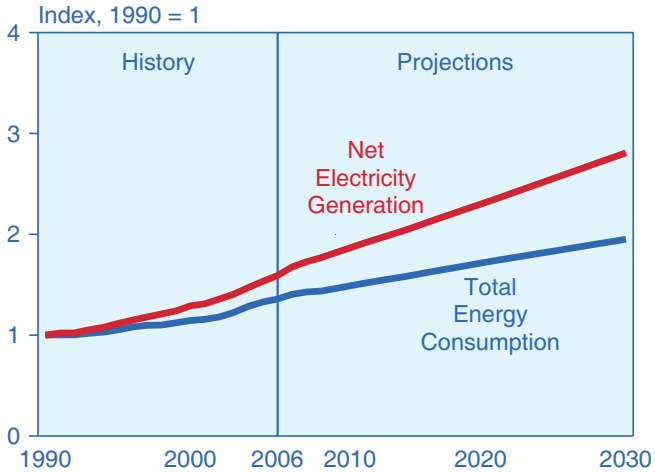
Electricity

World electricity generation increases by 77 percent from 2006 to 2030 in the IEO2009 reference case. The non-OECD countries are projected to account for 58 percent of world electricity use in 2030.

World net electricity generation increases by an average of 2.4 percent per year from 2006 to 2030 in the *IEO2009* reference case. Electricity is projected to supply an increasing share of the world's total energy demand and is the fastest-growing form of end-use energy worldwide in the mid-term. Since 1990, growth in net electricity generation has outpaced the growth in total energy consumption (2.9 percent per year and 1.9 percent per year, respectively), and the growth in demand for electricity continues to outpace growth in total energy use throughout the projection (Figure 48).

World net electricity generation increases by 77 percent in the reference case, from 18.0 trillion kilowatthours in 2006 to 23.2 trillion kilowatthours in 2015 and 31.8 trillion kilowatthours in 2030 (Table 10). Although the current recession is expected to dampen electricity demand in the near term, the reference case projection does not anticipate that the recession will be prolonged and expects growth in electricity demand to return to trend after 2010. The impact of the recession on electricity consumption is likely to be felt most strongly in the industrial sector, as manufacturing slows as a result of lower demand for manufactured products. Demand in the building sector is less sensitive to changing economic conditions than the industrial sector, because people generally continue to consume electricity for space heating and cooling, cooking, refrigeration, and hot water heating even in a recession.

Figure 48. Growth in World Electric Power Generation and Total Energy Consumption, 1990-2030



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. **Projections:** EIA, World Energy Projections Plus (2009).

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 goes unmet at present. The International Energy Agency estimates that nearly 32 percent of the population in the developing non-OECD countries (excluding non-OECD Europe and Eurasia) did not have access to electricity in 2005—a total of about 1.6 billion people [*1*]. Regionally, sub-Saharan Africa fares the worst: more than 75 percent of the population remains without access to power. High projected economic growth rates support strong increases in demand for electricity among the developing regions of the world through the end of the projection period.

The non-OECD nations consumed 45 percent of the world's total electricity supply in 2006, and their share of world consumption is poised to increase over the projection period. In 2030, non-OECD nations account for 58 percent of world electricity use, and the OECD share declines to 42 percent (Figure 49). In the developing countries, strong economic growth translates to growing demand for electricity. Increases in income per capita 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 net electricity generation in the non-OECD countries increases by an average of 3.5 percent per year in the reference case, led by non-OECD Asia (including China and India), with annual increases averaging 4.4 percent from 2006 to 2030 (Figure 50). In contrast, net generation among the OECD nations grows by an average of 1.2 percent per year from 2006 to 2030.

Electricity Supply by Energy Source

The mix of primary fuels used to generate electricity has changed a great deal over the past four decades on a worldwide basis. Coal continues 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 caused oil prices to increase to levels much higher than those for other fuels.

Although world oil prices contracted strongly at the end of 2008 and into 2009, the high prices recorded between 2003 and 2008, combined with concerns about the environmental consequences of greenhouse gas emissions, renewed interest in the development of alternatives to fossil fuels—specifically, nuclear power and renewable energy sources. The *IEO2009* reference case does not expect oil prices to remain at current levels. As economies begin to recover from the global recession, so too does the demand for liquids and other energy. As a result, long-term prospects continue to improve for generation from both nuclear and renewable energy sources—supported by government incentives and by high fossil fuel prices. Natural gas and coal are the second- and third fastest-growing sources of energy for electricity generation in the projection, although the outlook for coal, in particular, could be altered substantially by any future legislation that aims to reduce or limit the growth of greenhouse gas emissions.

Coal

In the *IEO2009* reference case, coal continues to fuel the largest share of worldwide electric power production, by a wide margin (Figure 51). In 2006, coal-fired generation accounted for 41 percent of world electricity supply; in 2030, its share is projected to be 43 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. World net coal-fired generation nearly doubles over the projection period, from 7.4 trillion kilowatthours in 2006 to 9.5 trillion kilowatthours in 2015 and 13.6 trillion kilowatthours in 2030.

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 energy for power generation and also the most carbon-intensive energy source. If a cost, either implicit or explicit, were applied to carbon dioxide emissions, there are several alternative no- or low-emission

Table 10. OECD and Non-OECD Net Electricty Generation by Energy Source, 2006-2030
(Trillion Kilowatthours)

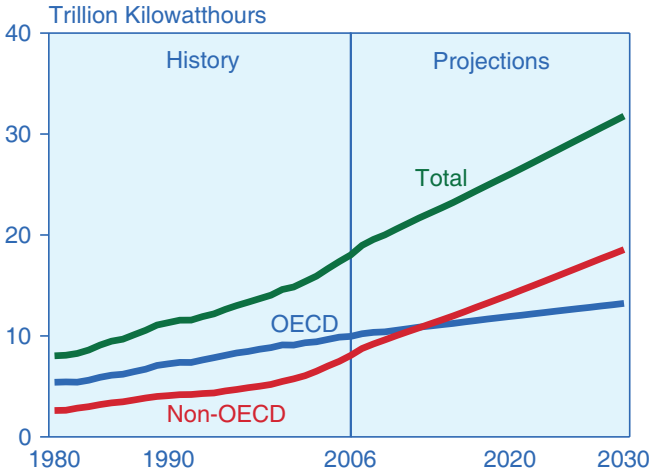
Region	2006	2010	2015	2020	2025	2030	Average Annual Percent Change, 2006-2030
OECD							
Liquids	0.3	0.3	0.3	0.3	0.3	0.3	-0.4
Natural Gas	2.0	2.2	2.4	2.7	3.0	3.1	1.8
Coal	3.7	3.9	4.0	4.0	4.0	4.3	0.6
Nuclear	2.2	2.3	2.4	2.4	2.5	2.6	0.6
Renewables	1.6	1.9	2.2	2.5	2.8	2.9	2.5
Total OECD	**9.9**	**10.6**	**11.3**	**11.9**	**12.6**	**13.2**	**1.2**
Non-OECD							
Liquids	0.6	0.6	0.6	0.6	0.6	0.6	0.1
Natural Gas	1.6	2.0	2.5	3.0	3.4	3.7	3.6
Coal	3.7	4.8	5.5	6.4	7.8	9.2	3.9
Nuclear	0.4	0.5	0.7	0.9	1.2	1.3	4.8
Renewables	1.8	2.2	2.7	3.2	3.4	3.8	3.2
Total Non-OECD	**8.0**	**10.0**	**12.0**	**14.1**	**16.3**	**18.6**	**3.5**
World							
Liquids	0.9	0.9	0.9	0.9	0.9	0.9	-0.1
Natural Gas	3.6	4.2	4.9	5.7	6.4	6.8	2.7
Coal	7.4	8.7	9.5	10.4	11.8	13.6	2.5
Nuclear	2.7	2.8	3.0	3.4	3.6	3.8	1.5
Renewables	3.4	4.1	4.9	5.7	6.1	6.7	2.9
Total World	**18.0**	**20.6**	**23.2**	**26.0**	**28.9**	**31.8**	**2.4**

Note: Totals may not equal sum of components due to independent rounding.
Sources: **2006:** Derived from Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. **Projections:** EIA, World Energy Projections Plus (2009).

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.

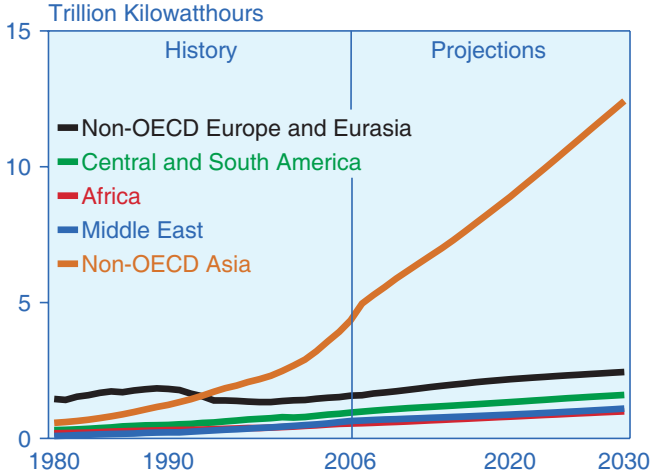
It could be more difficult, however, to achieve similar results in other end-use sectors. In the transportation sector, for instance, large-scale reduction of carbon dioxide emissions probably would require extensive changes in the motor vehicle fleet, fueling stations, and fuel distribution systems, 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.

Figure 49. World Net Electric Power Generation, 1980-2030



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. **Projections:** EIA, World Energy Projections Plus (2009).

Figure 50. Non-OECD Net Electricity Generation by Region, 1980-2030



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. **Projections:** EIA, World Energy Projections Plus (2009).

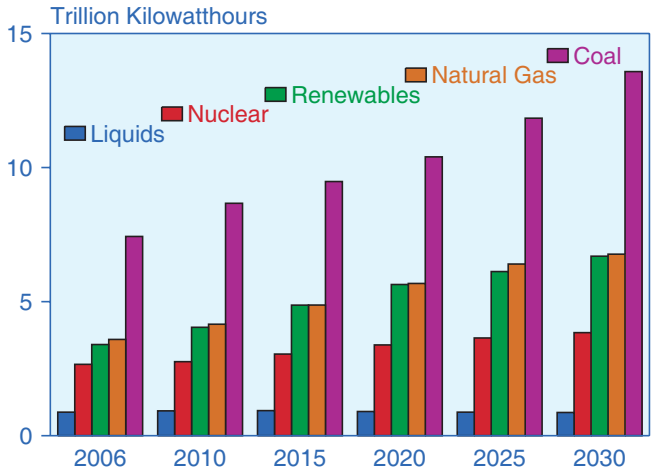
Natural Gas

Over the 2006 to 2030 projection period, natural-gas-fired electricity generation increases by 2.7 percent per year, making gas the fastest-growing power source after renewables in the *IEO2009* reference case. Generation from natural gas worldwide increases from 3.6 trillion kilowatthours in 2006 to 6.8 trillion kilowatthours in 2030, but 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 online 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.

Liquid Fuels and Other Petroleum

With world oil prices projected to return to relatively high levels, reaching $130 per barrel (in real 2007 dollars) in 2030, liquids are the only energy source for power generation that does not grow on a worldwide basis. Most nations are expected to respond to high oil prices by reducing or eliminating their use of oil for generation—opting instead for more economical sources of electricity, including coal. Although the recent decline in world oil prices has forestalled the retreat from oil-fired generation in the near term, nations turn to alternative

Figure 51. World Electricity Generation by Fuel, 2006-2030



Sources: **2006:** Derived from Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. **Projections:** EIA, World Energy Projections Plus (2009).

fuels for their power sources as oil prices rebound. From 2006 to 2015, oil-fired generation grows by 0.7 percent per year; thereafter, with world oil prices above $100 per barrel and rising after 2015, generation from liquids falls by an average of 0.5 percent per year. Modest growth in liquids generation in the later years of the projection, particularly in the Middle East, is more than offset by declines in all other regions.

Nuclear Power

Electricity generation from nuclear power is projected to increase from about 2.7 trillion kilowatthours in 2006 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.

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. Still, there is considerable uncertainty associated with nuclear power. 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. Those issues continue to raise public concern in many countries and may hinder the development of new nuclear power reactors. Nevertheless, the *IEO2009* reference case incorporates improved prospects for world nuclear power. The *IEO2009* projection for nuclear electricity generation in 2025 is 25 percent higher than the projection published 5 years ago in *IEO2004*.

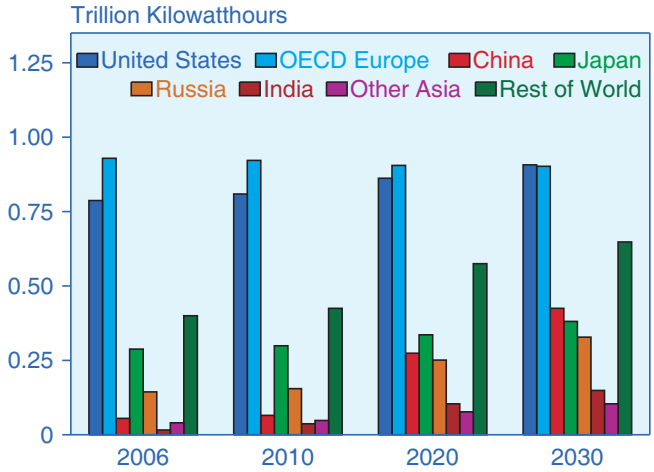
On a regional basis, the *IEO2009* reference case projects the strongest growth in nuclear power for the countries of non-OECD Asia (Figure 52). Non-OECD Asia's nuclear power generation is projected to grow at an average annual rate of 7.8 percent from 2006 to 2030, including projected increases of 8.9 percent per year in China and 9.9 percent per year in India. 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 3.5 percent per year. In contrast, OECD Europe is expected to see a small decline in nuclear power generation, as some national governments (including Germany and Belgium) still have plans in place to phase out nuclear programs entirely.

To address the uncertainty inherent in projections of nuclear power growth in the long term, a two-step approach is used to formulate the outlook for nuclear power. In the near 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 on which nuclear projects 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 is also considered as part of the *IEO2009* modeling effort. At production costs between $40 and $80 per kilogram of uranium, total uranium reserves in excess of 3.8 billion metric tons will be sufficient to meet the 2.7 billion metric tons that would be needed to support the projected growth in nuclear generation worldwide [2].

Hydroelectric, Wind, Geothermal, and Other Renewable Generation

Renewable energy is the fastest-growing source of electricity generation in the *IEO2009* reference case. Total generation from renewable resources increases by 2.9 percent annually, and the renewable share of world electricity generation grows from 19 percent in 2006 to 21 percent in 2030. Much of the increase is expected to be in hydroelectric power and wind power. Generation from

Figure 52. World Net Electricity Generation from Nuclear Power by Region, 2006-2030



Sources: **2006:** Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. **Projections:** EIA, World Energy Projections Plus (2009).

wind energy, in particular, has grown swiftly over the past decade, from 11 gigawatts of net installed capacity at the beginning of 2000 to 121 gigawatts at the end of 2008—a trend that is projected to continue into the future [3]. Of the 3.3 trillion kilowatthours of new renewable generation added over the projection period, 1.8 trillion kilowatthours (54 percent) is attributed to hydroelectric power and 1.1 trillion kilowatthours (33 percent) to wind (Table 11).[22]

Although renewable energy sources have positive environmental and energy security properties, most renewable technologies other than hydroelectricity are not able to compete economically with fossil fuels during the projection period outside a few regions. Solar power, for instance, is currently a "niche" source of renewable energy but can be economical where electricity prices are especially high or government incentives are available (see box on page 68). In fact, government policies or incentives often provide the primary motivation for construction of renewable generation facilities.

Changes in the mix of renewable fuels used for electricity generation are expected to differ between the OECD and non-OECD regions in the *IEO2009* reference case. In the OECD nations, the majority of economically exploitable hydroelectric resources already have been used; and, with the exceptions of Canada and Turkey, there are few large-scale hydroelectric power projects planned for the future. As a result, most renewable energy growth in the OECD countries is expected to come from nonhydroelectric sources, especially wind and biomass. Many OECD countries, particularly those in Europe,

Table 11. OECD and Non-OECD Renewable Electricty Generation by Energy Source, 2006-2030
(Billion Kilowatthours)

Region	2006	2010	2015	2020	2025	2030	Average Annual Percent Change, 2006-2030
OECD							
Hydropower	1,274	1,321	1,396	1,447	1,496	1,530	0.8
Wind	113	258	418	572	713	842	8.7
Geothermal	35	45	54	57	59	62	2.4
Other	212	263	354	438	487	513	3.7
Total OECD	**1,635**	**1,888**	**2,222**	**2,515**	**2,756**	**2,948**	**2.5**
Non-OECD							
Hydropower	1,723	2,060	2,491	2,911	3,098	3,242	2.7
Wind	14	53	82	115	150	372	14.6
Geothermal	19	29	40	42	45	47	3.8
Other	33	41	64	83	100	114	5.3
Total Non-OECD	**1,790**	**2,184**	**2,676**	**3,151**	**3,393**	**3,776**	**3.2**
World							
Hydropower	2,997	3,381	3,887	4,359	4,594	4,773	2.0
Wind	127	312	500	687	864	1,214	9.9
Geothermal	55	75	93	99	104	109	2.9
Other	246	304	418	521	587	628	4.0
Total World	**3,424**	**4,072**	**4,898**	**5,666**	**6,149**	**6,724**	**2.9**

Notes: Totals may not equal sum of components due to independent rounding. Numbers for the United States in this table are based on the *published AEO2009* reference case (March 2009). In the *updated AEO2009* reference case (April 2009), which incorporates provisions from ARRA2009 that stimulate increased renewable generation, a significant expansion in the use of renewable fuels is projected. As a result, in the projections for 2030, total world electricity generation from hydropower rises to 4,771 billion kilowatthours, total generation from wind rises to 1,291 billion kilowatthours, total generation from geothermal energy rises to 111 billion kilowatthours, and total generation from other renewables rises to 594 billion kilowatthours.

Sources: **2006:** Derived from Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. **Projections:** EIA, World Energy Projections Plus (2009).

[22] In the *updated AEO2009* reference case (April 2009), a significant expansion in U.S. use of renewable fuels for electricity generation is projected, particularly in the near term. An extension of key Federal tax credits and a new loan guarantee program in ARRA2009 both stimulate increased renewable generation relative to the projection in the *published AEO2009* reference case (March 2009). U.S. renewable generation in 2030 is 9 percent higher in the *updated* reference case than in the *published* reference case. As a result, incorporating the U.S. projections from the *updated AEO2009* reference case results in an increase in total world renewable generation of 3.4 trillion kilowatthours over the projection period, of which 1.8 trillion kilowatthours (53 percent of the total increase) is hydroelectric power and 1.2 trillion kilowatthours (35 percent) is wind power.

Solar Photovoltaic and Solar Thermal Electric Technologies

Solar power is one of the fastest-growing sources of renewable energy worldwide. Many nations, concerned about the environmental impacts of electricity generation from fossil fuels or from large-scale hydroelectric plants, have been turning to solar power as an environmentally benign alternative. The solar energy that reaches the earth can be harnessed to generate electric power, and the potential for large-scale applications of solar power has improved markedly in recent years. Two solar power technologies—solar photovoltaic and solar thermal—are widely employed today, and their use is likely to increase in the future.

Solar photovoltaic technologies convert sunlight directly into electricity by using photons from the sun's light to excite electrons into higher states of energy. The resultant voltage differential across cells allows for a flow of electric current. Because individual solar cells are very small and produce a few watts of power at most, they are connected together in solar panels that can be arranged in arrays to increase electricity output. The arrangement of arrays is one major advantage of photovoltaic technologies, because they can be made in virtually any size to fit a specific application.

One popular application of solar photovoltaics is in solar panel installations on residential roofs, which can be scaled to accommodate house size and electricity needs. Although the technology now is used most often in small residential applications, it can be scaled up to create larger power plants, such as the 14-megawatt Nellis solar plant in Nevada with some 70,000 panels and the 11-megawatt solar plant in Serpa, Portugal, with 52,000 panels.

At present, the cost of electricity produced from solar photovolatics generally is too high to compete with wholesale electricity. In sunny locations, however, the cost can be as low as 23 cents per kilowatthour,[a] which may be competitive with the delivered price of electricity to retail customers in areas where electricity prices are high, as they are in California, Southern Spain, and Italy.[b] On the basis of installed cost per megawatt, solar photovoltaic installations are relatively costly, because the panel components are expensive and the conversion of solar energy to electricity in the cells still is inefficient. From conversion efficiencies of 5 to 6 percent for the first solar cells built in the 1950s, there has been an improvement to efficiencies of 12 to 18 percent for modern commercial wafer-silicon cells.[c]

Efficiency gains, coupled with other technological advances, have reduced the cost of solar photovoltaic capacity from approximately $300 per watt in 1956[d] to less than $5 per watt in 2009.[e] EIA's *Annual Energy Outlook 2009* projects that, by 2030, overnight capacity costs for new generating plants using solar photovoltaics will be 37 percent lower than the 2009 costs. In addition, the efficiency of solar photovoltaic applications is expected to improve as the technology continues to be developed. As a result, U.S. solar photovoltaic generating capacity is projected to increase from 30 megawatts in 2006 to 381 megawatts in 2030 (see figures on page 69).

Although prices for electricity from photovoltaics may not become widely competitive with wholesale prices for electricity from conventional generating technologies within the next 25 years, they may be competitive with high retail electricity prices in sunny regions. Already, photovoltaic technology is gaining market share in countries where declining prices and government-backed financial incentives have led to increased usage. In Germany, for example, a feed-in tariff of 27 cents per kilowatthour[f] has produced an explosion in the use of solar photovoltaics, and in Japan the government has set a target for 30 percent of all households to have solar panels installed by 2030.

Solar thermal technologies produce electricity by concentrating the sun's heat to boil a liquid and using the steam to rotate a generator turbine, in much the same way that electricity is produced from steam plants powered by coal or natural gas. There are two main types of solar thermal power plants: towers and parabolic troughs. A solar power tower consists of a large array of sun-tracking mirrors, which are used to reflect the sun's rays onto a central tower. When the rays hit the tower's receiving panel, their heat is transferred to a fluid medium that is boiled to produce steam. Solar power towers have been demonstrated successfully,

(continued on page 69)

[a]U.S. Department of Energy, *Solar Energy Technologies Program Multi Year Program Plan 2008-2012* (Washington, DC, April 18, 2008), p. 18, web site www1.eere.energy.gov/solar/pdfs/solar_program_mypp_2008-2012.pdf. In comparison, wholesale electricity prices averaged 5.42 cents per kilowatthour in California in 2009.

[b]Because retail electricity prices in the United States include generation, transmission, and distribution costs, prices paid by consumers are higher than average retail prices per kilowatthour.

[c]U.S. Department of Energy, *Solar Energy Technologies Program Multi Year Program Plan 2008-2012*, p. 119.

[d]Southface Energy Institute, "History of Solar," web site www.southface.org/solar/solar-roadmap/solar_how-to/history-of-solar.htm.

[e]Solarbuzz LLC, "Solar Module Retail Price Environment," web site www.solarbuzz.com/Moduleprices.htm.

[f]Under a feed-in tariff structure, regional or national electric utilities are obligated to purchase renewable electricity at a higher rate than retail, in order to allow renewable energy sources to overcome price disadvantages.

Solar Photovoltaic and Solar Thermal Electric Technologies (continued)

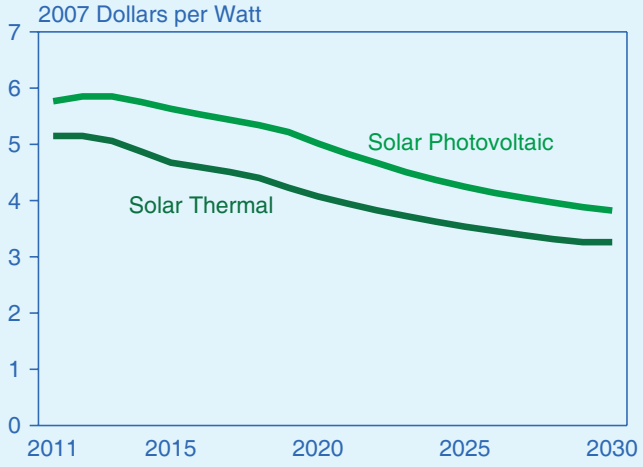
but they still are in the early stages of technology development. The world's largest solar power tower, located in Spain, is the 15-megawatt Solar Tres Power Tower.

The most commonly used solar thermal technology is the parabolic trough, in which a parabolic reflector focuses the sun's rays on a heat pipe that runs the length of the trough and transports heated fluid to a central power station. Most parabolic trough installations consist of a field of reflectors concentrated on a central location, where the working fluid is heated to produce steam. The world's largest parabolic trough installation is the Kramer Junction Solar Electric Generating System in California, which consists of five 30-megawatt parabolic trough arrays. Total U.S. installed solar thermal capacity, currently 400 megawatts, is projected to increase to 859 megawatts in 2030 (see figure below).

Solar thermal power plants are designed to be large-scale grid-connected plants, but at present they generally cannot be used as baseload generators, because they do not produce heat at night or during the day when clouds block the sun. Some advances have been made in storing solar energy by using it to heat liquid sodium, which can be used later to boil water and produce the steam needed to power a generator turbine. The process is time-limited, however, and can extend a plant's operations by only a few hours at best. In some cases, storage times of 4 to 16 hours have been achieved, sufficient to allow electricity from solar thermal generators to be sold when it is more valuable, during the peak demand hours of 7-9 am and 5-7 pm.

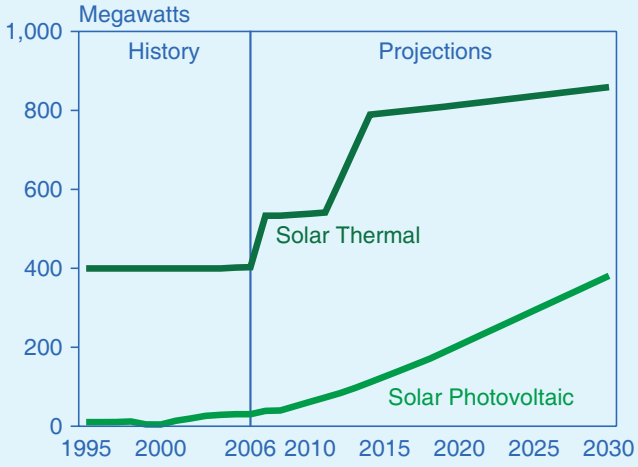
Solar technologies have benefited from much research and development over the past two decades, bringing down the delivered price of solar electricity. Today, electricity from residential photovoltaics is marketed to compete with high-priced retail electricity. In the future, it is possible that utility-scale photovoltaic plants will compete with wholesale electricity generation, provided that further technological advances are achieved. Solar thermal power plants are intended to compete with wholesale generation, especially from peaking plants, and they may become more competitive over time if heat storage technologies improve, costs decrease, and/or policies to mitigate carbon dioxide emissions are adopted.

Projected U.S. Average Installed Capital Costs for New Solar Electricity Generating Plants, 2011-2030



Source: Energy Information Administration, AEO2009 National Energy Modeling System, run AEO2009.D120908A.

U.S. Solar Thermal and Solar Photovoltaic Installed Net Summer Generating Capacity, 1995-2030



Source: Energy Information Administration, AEO2009 National Energy Modeling System, run AEO2009.D120908A.

have government policies, including feed-in tariffs,[23] tax incentives, and market share quotas, that encourage the construction of renewable electricity facilities.

In the non-OECD countries, hydroelectric power is expected to be the predominant source of renewable energy growth. Strong growth in hydroelectric generation,

[23] A feed-in tariff is an incentive structure to encourage the adoption of renewable energy through government legislation. Under a feed-in tariff structure, regional or national electricity utilities are obligated to purchase renewable electricity at a higher rate than retail, guaranteeing the renewable generator a positive return on its investment and allowing renewable energy sources to overcome price disadvantages.

primarily from mid- to large-scale power plants, is expected in China, India, Brazil, and a number of nations in Southeast Asia, including Vietnam and Laos. Growth rates for wind-powered generation also are expected to be high in non-OECD countries. The most substantial additions of electricity supply generated from wind power may be centered in China.

The *IEO2009* projections for renewable energy sources include only marketed renewables. Non-marketed (non-commercial) biofuels from plant and animal resources are an important source of energy, however, particularly in the developing non-OECD economies. The International Energy Agency has estimated that approximately 2.5 billion people in developing countries depend on traditional biomass as their main cooking fuel [*4*]. Non-marketed fuels and distributed renewables (renewable energy consumed at the site of production, such as off-grid solar photovoltaic panels) are not included in the projections, however, because comprehensive data on their use are not available. Further, the full impacts of the current global economic downturn and credit crisis on the potential for growth of marketed renewable generation are not known. The reference case assumes that these issues may delay some projects in the short term but will not affect the long-term growth of electricity generation from renewable resources.

Regional Outlook

In the *IEO2009* 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—demand for electricity is projected to grow much more slowly than in the non-OECD countries. In the reference case, non-OECD electricity generation increases by 3.5 percent per year, as compared with 1.2 percent per year in the OECD nations.

OECD Economies

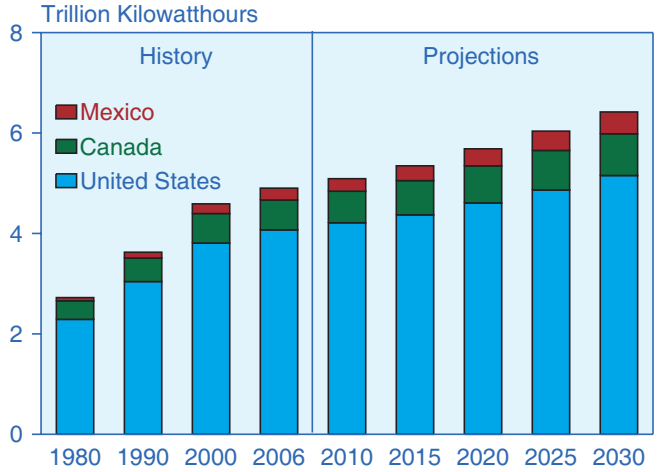
North America

North America currently accounts for the largest regional share of world electricity generation, at 27 percent of the total in 2006. That share declines over the course of the projection period, as the non-OECD nations experience fast-paced growth in demand for electric power. 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 53). U.S. electricity generation—including both generation by electric power producers and on-site generation—increases slowly, at an average annual rate of 1.0 percent.[24] Canada, like the United States, has a mature electricity market, and its generation is projected to increase by 1.4 percent per year from 2006 to 2030. Mexico's electricity generation grows at a faster rate—averaging 2.8 percent per year through 2030—reflecting the underdeveloped state of the country's electric power infrastructure (and thus the greater potential for expansion) relative to Canada and the United States.

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 54). In the United States, coal is the leading source of energy for power generation, accounting for 49 percent of the 2006 total; but in Canada, hydroelectricity provided 59 percent of the nation's electricity generation in 2006. Most of Mexico's electricity generation currently is fueled by petroleum-based liquids and natural gas, which together accounted for 60 percent of its total electricity generation in 2006. In the reference case, U.S. reliance on coal decreases slightly, to 47 percent in

Figure 53. Net Electricity Generation in OECD North America, 1980-2030



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. **Projections:** EIA, World Energy Projections Plus (2009).

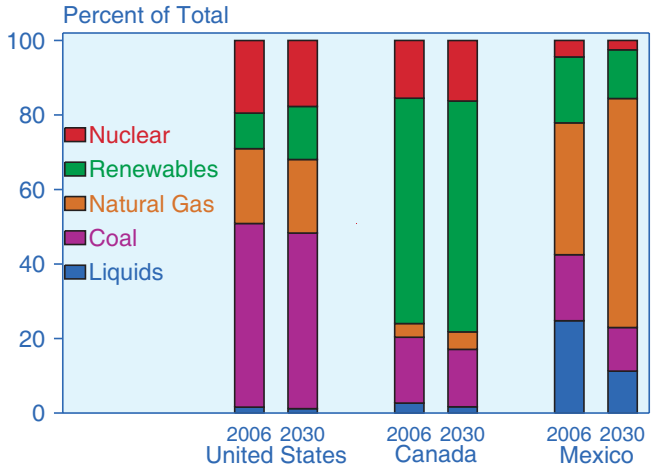
[24] Primarily as the result of slower macroeconomic growth, U.S. net electricity generation grows more slowly (averaging 0.9 percent per year) in the *updated AEO2009* reference case (April 2009) than in the *published AEO2009* reference case (March 2009) discussed in this report.

2030;[25] Canada's hydropower continues to be the predominant energy source for electricity generation, although its share of the total falls to 54 percent in 2030; and the natural gas share of Mexico's total electricity generation increases from 35 percent in 2006 to 62 percent in 2030.

Although coal remains the most important fuel for U.S. electricity generation, slower growth in the demand for electricity and increasing concern about greenhouse gas emissions affect the coal markets by slowing the growth in demand for coal-fired generation in this year's outlook relative to the *IEO2008* projection. Even though the mix of investments in new power plants relies less on coal than in recent outlooks, however, coal remains the dominant fuel for generation because of continued reliance on existing coal-fired plants and the addition of some new ones in the absence of an explicit policy to reduce greenhouse gas emissions.

In contrast to coal, natural gas plays a larger role in U.S. generation projections than in recent *IEO*s, because it is less carbon intensive than coal, and because it is much less expensive to build new natural-gas-fired plants than to build either new renewable or new nuclear plants. Electricity generation from natural gas in 2030 is 37 percent higher in the *IEO2009* reference case than was projected in the *IEO2008* reference case.[26] A key factor in the change is slower growth in coal use as a result of environmental concerns and the possible impacts of related future policies that would reduce the number of new coal-fired plants added.

Figure 54. Net Electricity Generation in OECD North America by Fuel, 2006 and 2030



Sources: **2006:** Derived from Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. **2030:** EIA, World Energy Projections Plus (2009).

Generation from renewable energy sources in the United States increases in response to requirements in more than one-half of the 50 States for minimum renewable generation or capacity shares. Renewable generation in the *IEO2009* reference case is substantially higher than in last year's projections, with the share of generation coming from renewable energy sources growing from 9.5 percent in 2006 to 14.2 percent in 2030.[27] Federal subsidies for renewable generation are assumed to expire as enacted; however, if those subsidies were extended, a much larger increase in renewable generation would be expected.

Electricity generation from nuclear power plants accounts for 18 percent of total U.S. generation in 2030 in the *IEO2009* reference case.[28] From 2006 to 2030, the United States is expected to add 12.7 gigawatts of capacity at newly built nuclear power plants and 3.7 gigawatts from uprates of existing plants—offset in part by the retirement of 4.4 gigawatts of capacity at older nuclear power plants. The increase in U.S. nuclear capacity is attributed to policies enacted to spur nuclear power growth, as well as concerns about greenhouse gas emissions, which limit additions of coal-fired plants in the projection.

In Canada, generation from natural gas is projected to increase by 2.5 percent per year from 2006 to 2030, while coal-fired generation increases by 0.8 percent per year, nuclear by 1.5 percent per year, hydroelectricity by 1.0 percent per year, wind by 13.1 percent per year, and other renewable energy sources by 3.5 percent per year. Oil-fired generation, on the other hand, declines by 0.6 percent per year.

[25] Primarily as the result of additional incentives for renewable fuels included in ARRA2009, U.S. coal-fired generation in 2030 is slightly lower in the *updated AEO2009* reference case (April 2009) than in the *published* reference case (March 2009). As a result, coal's share of total U.S. electricity generation in 2030 is slightly lower (at 46 percent) in the *updated* reference case.

[26] Primarily as a result of lower assumptions for macroeconomic growth in the *updated AEO2009* reference case (April 2009), U.S. natural-gas-fired generation in 2030 is about 4 percent lower than in the *published* reference case (March 2009).

[27] In the *updated AEO2009* reference case (April 2009), a significant expansion in the use of renewable fuels for U.S. electricity generation is projected, particularly in the near term. An extension of key Federal tax credits and a new loan guarantee program in ARRA2009 both stimulate increased renewable generation relative to the *published* reference case (March 2009). In 2030, U.S. renewable electricity generation is about 9 percent higher in the *updated* reference case and accounts for 15.8 percent of total U.S. net generation.

[28] Additional incentives for renewable energy and improved energy efficiency measures included in ARRA2009 lower the prospects for U.S. nuclear power. In the *updated AEO2009* reference case (April 2009), the projection for U.S. nuclear generating capacity in 2030 is 2.5 gigawatts lower than in the *published* reference case (March 2009), and the net addition to U.S. installed nuclear capacity between 2006 and 2030 is 9.9 gigawatts, bringing the 2030 total to 110.1 gigawatts in the *updated* reference case, as compared with 112.6 gigawatts in the *published* reference case. In both cases, nuclear generation accounts for 18 percent of total U.S. net generation in 2030.

In Ontario—Canada's largest provincial electricity consumer—the government maintains that it will close its four coal-fired plants (Atikokan, Lambton, Nonticoke, and Thunder Bay) by December 31, 2014, citing environmental and health concerns [*5*]. The government plans to replace coal-fired capacity with natural gas, nuclear, hydroelectricity, and wind, along with increased conservation measures. At present, coal provides about 16 percent of Ontario's electric power. In the *IEO2009* reference case, the retirement of Ontario's coal-fired facilities is offset by increases elsewhere in the country—notably, Alberta and Nova Scotia. As a result, Canada's coal-fired generation rises modestly, from about 106 billion kilowatthours in 2006 to 128 billion kilowatthours in 2030.

Hydroelectric power is, and is expected to remain, the primary source of electricity in Canada. In 2006, hydroelectric generation provided 59 percent of the country's total generation. While the hydropower share falls to 54 percent in 2030, wind's share grows from less than 1 percent in 2006 to 6 percent in 2030. As a result, the renewable share of Canada's overall generation remains roughly constant throughout the projection.

As one of the few OECD countries with untapped hydroelectric potential, Canada currently has several large- and small-scale hydroelectric facilities currently either planned or under construction. Hydro-Québec has announced plans to construct a 768-megawatt facility near Eastman and a smaller 125-megawatt facility at Sarcelle in Québec, both of which are expected to be fully commissioned by 2012 [*6*]. 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 [*7*]. The *IEO2009* 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 15,610 megawatts of additional renewable capacity projected to be added in Canada between 2006 and 2030.

Canada also has plans to continue expanding its wind power capacity. From 2,246 megawatts of installed capacity at the beginning of 2009 [*8*], the total is projected to increase to nearly 24,000 megawatts in 2030 in the reference case. Almost 3,000 megawatts of wind capacity is currently under construction or under development in Quebec alone. Growth in wind capacity has been so rapid that Canada's federal wind incentive program, "ecoENERGY for Renewable Power," which allows the deployment of 4,000 megawatts of renewable energy by 2011, will use the remainder of its funding by the end of 2009 [*9*].

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 780 megawatts in January 2009 [*10*]. 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 [*11*] 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. Continued support from Canada's federal and provincial governments—along with the sustained higher world oil prices in the *IEO2009* reference case—is expected to provide momentum for the projected increase in the country's use of wind power for electricity generation.

Mexico's electricity generation increases by an average of 2.8 percent annually from 2006 to 2030—double the rate for Canada and triple the rate for the United States. The Mexican government has recognized the need for the country's electricity infrastructure to keep pace with the fast-paced growth anticipated for electricity demand. In July 2007, the government unveiled its 2007-2012 National Infrastructure Programme, which included plans to invest $25.3 billion to improve and expand electricity infrastructure [*12*]. As part of the program, the government has set a goal to increase installed generating capacity by 8.6 gigawatts from 2006 to 2012. The country is well on its way to meeting the government target. The 1,135-megawatt Tamazunchale combined-cycle plant became operational in June 2007 (and there are plans to expand the generating capacity to 5,000 megawatts eventually), and several other plants under construction will bring on line another 840 megawatts in 2009, 650 megawatts in 2010, and 750 megawatts in 2012 [*13*].

Most of the projected increase in Mexico's electricity generation in the *IEO2009* reference case is fueled by natural gas, as the Mexican government implements plans to reduce the country's use of diesel and fuel oil in the power sector [*14*]. Natural-gas-fired generation is more than triples in the projection, from 80 billion kilowatthours in 2006 to 268 billion kilowatthours in 2030. The resulting growth in Mexico's demand for natural gas strongly outpaces its growth in production, leaving the country dependent on pipeline imports from the United States and LNG from other countries. Currently, Mexico has one LNG import terminal, Altimira,

operating on the Gulf Coast and another, Costa Azul, on the Pacific Coast. A contract tender for a third terminal at Manzanillo, also on the Pacific Coast, was awarded in March 2008, and the project is scheduled for completion by 2011 [***15***]. New coal-fired plants also are planned, to help diversify the fuel mix for power generation. The 651-megawatt Pacifico coal-fired plant currently is under construction, with a scheduled completion date of 2010 [***16***].

Although much of the growth in Mexico's electric power sector is expected to be in the form of natural-gas-fired generation, renewable energy resources are expected to be the second fastest-growing source of generation in the projection. Mexico's renewable generation increases by 1.5 percent per year from 2006 to 2030, compared with a 5.2 percent per year for natural-gas-fired generation. The country's current renewable generation energy mix is split largely between hydroelectricity (76 percent) and geothermal energy (17 percent). Two major hydroelectric projects are under way: the 750-megawatt La Yesca facility, which is scheduled for completion by 2012, and the planned 900-megawatt La Parota project, which is expected to be completed by 2015 [***17***].

Mexico also plans to add substantial wind generation to its power resource mix. During 2006 alone, the country's installed wind capacity increased from 2.2 megawatts to 86.5 megawatts [***18***]. Although no additional wind capacity was installed in Mexico in 2008, there are ambitious plans to add another 700 megawatts of wind capacity by 2010, including 400 megawatts planned by independent power producers and a 100-megawatt expansion of the existing 83-megawatt La Venta wind farm [***19***].

OECD Europe

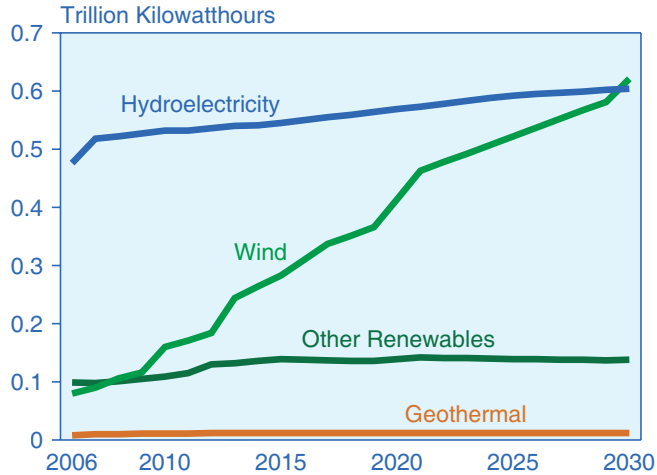
Electricity generation in the nations of OECD Europe increases by an average of 1.3 percent per year in the *IEO2009* reference case, from 3.4 trillion kilowatthours in 2006 to 4.0 trillion kilowatthours in 2015 and 4.6 trillion kilowatthours in 2030. Because most of the countries in OECD Europe have relatively stable populations and mature electricity markets, most growth in electricity demand is expected to come from those nations 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. In addition, as environmental concerns remain prominent in the region, there is a concerted effort to switch from coal and liquids use to electricity in the industrial sector.

Renewable energy is OECD Europe's fastest-growing source of electricity generation in the *IEO2009* reference case. The use of renewables for electricity generation is projected to grow by 3.1 percent per year through 2030, and the increase is almost entirely from nonhydropower sources. Because most of the economically feasible hydroelectric resources in Europe already have been developed, the countries of OECD Europe have switched their focus to alternative renewable energy capacity—consisting mainly of wind turbines—over the past decade. At present, seven of the world's ten largest markets for wind-powered electricity generation are in Europe,[29] and the 27-member European Union accounted for 54 percent of the world's total installed wind capacity at the end of 2008 [***20***].

OECD Europe's leading position worldwide in wind power capacity is projected to be maintained through 2030, with growth in generation from wind sources averaging 8.9 percent per year, even though the reference case assumes no enactment of additional international legislation to limit greenhouse gas emissions during the period. The robust growth in wind power, coupled with a mature hydropower sector, causes electricity generation from wind power to surpass hydroelectric generation by the end of the projection period (Figure 55). A lack of additional land for installation of new wind turbines will force many European countries either to "repower" their existing fleets by replacing old turbines with larger, more effective (higher capacity rated) ones or to build significant portions of future capacity offshore, especially in the North Sea and Baltic Sea.

The growth of nonhydropower renewable energy sources in OECD Europe is encouraged by some of the

Figure 55. Renewable Electricity Generation in OECD Europe by Fuel, 2006-2030



Sources: **2006:** Derived from Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. **Projections:** EIA, World Energy Projections Plus (2009).

[29] According to the Global Wind Energy Council, at the end of 2008 the 10 countries with the largest amounts of installed wind capacity were the United States, Germany, Spain, China, India, Italy, France, the United Kingdom, Denmark, and Portugal.

world's most favorable renewable energy policies. The European Union has set a binding target to produce 21 percent of electricity generation from renewable sources by 2010 [**21**] and has reaffirmed the goal of increasing renewable energy use with its December 2008 "climate and energy policy," which mandates that 20 percent of total energy production must come from renewables by 2020 [**22**]. Approximately 19 percent of the European Union's electricity came from renewable sources in 2006.

The *IEO2009* reference case does not anticipate that all the renewable energy targets in the European Union will be met on time, especially because of the uncertain impact of the current economic and fiscal conditions on the financing of electricity projects and the adherence to stated goals. Nevertheless, current laws are expected to lead to the construction of more renewable capacity than would have occurred in their absence. In addition, some individual countries provide economic incentives to promote the expansion of renewable electricity. Germany, Spain, and Denmark—the leaders in OECD Europe's installed wind capacity—have enacted feed-in tariffs that guarantee above-market rates for electricity generated from renewable sources and, typically, last for 20 years from the completion of a power plant. As long as European governments support such price premiums for renewable electricity, robust growth in renewable generation is likely to continue.

Natural gas is the second fastest-growing source of power generation after renewables in the outlook for OECD Europe, increasing at an average rate of 2.3 percent per year from 2006 to 2030. Although the growth still is quite strong considering that total electricity demand increases by only 1.3 percent per year, it is somewhat slower than the 3.9-percent annual increase projected for natural-gas-fired generation in last year's outlook. The difference results in part from the more robust growth projected for the region's renewable generation and in part from concerns about the security of power supplies. Russia is Europe's major natural gas supplier, and in 2009, for the second time since 2006, it cut off deliveries of natural gas through Ukraine in a dispute with that country over pricing. Although natural gas storage and LNG supplies were sufficient to prevent OECD Europe from being physically affected by the cutoff, the event did underscore Europe's dependence on Russian supplies, particularly as domestic regional production continues to decline. Nearly 65 percent of Russia's exported natural gas is delivered through Ukraine, which is substantially lower than in 1998 (95 percent) but still much higher than Russia's 2015 goal of 40 percent [**23**].

Nuclear power has gained renewed interest in Europe as concerns about greenhouse gas emissions and secure electricity supplies have increased. Although OECD Europe's total nuclear capacity declines from 132 gigawatts in 2006 to 119 gigawatts in 2020 in the reference case, that decrease is followed by a net increase to 121 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 their planned closures of nuclear power plants actually will take place, given that nuclear plants provide baseload capacity while producing no carbon dioxide emissions. Further, many European nations previously staunchly against nuclear power have been revisiting their stances. Sweden's government, for instance, announced in February 2009 that it would move to halt its plan to phase out nuclear power by 2010 and reverse its 30-year ban on building new nuclear capacity [**24**]. Italy has also announced its intention to diversify its electric power fuel mix by building nuclear power plants [**25**].

Renewed interest and moves to reverse legislative bans on nuclear power have led to more license extensions and fewer retirements of operating nuclear power plants than were expected in assessments in previous outlooks. In addition, the *IEO2009* reference anticipates some new builds (about 18 gigawatts of new nuclear capacity) in France, Finland, and possibly other countries of OECD Europe. On the other hand, the significant investments being made in renewable energy sources may lessen the opportunities for new nuclear capacity.

Coal accounted for nearly 30 percent of OECD Europe's net electricity generation in 2006, 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, it may be difficult to reduce coal use substantially and at the same time carry out plans to dismantle nuclear power programs, in spite of the strong growth projected for renewable generation. In particular, coal provides about 55 percent of total electricity generation in Germany and 95 percent in Poland [**26**]. In the *IEO2009* reference case, electricity from coal remains an important part of supply in OECD Europe, increasing at a relatively slow average rate of 0.1 percent per year from 2006 to 2030.

OECD Asia

Total electricity generation in OECD Asia increases by an average of 1.2 percent per year in the reference case, from 1.7 trillion kilowatthours in 2006 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 having the slowest-growing electricity market in the region and the slowest among all the OECD countries, averaging 0.6-percent per year, as compared with 1.5 percent per year for Australia/New Zealand and 2.3

percent per year for South Korea (Figure 56). 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 28 percent. The remaining portion is split between renewables and petroleum-based liquids. Japan's reliance on nuclear power and natural gas is projected to increase somewhat over the projection period, to 60 percent of total generation in 2030. Coal's share of generation declines to 22 percent, being displaced by natural gas, nuclear, and—to a much smaller extent—renewable energy sources.

As is true for much of the OECD, wind power is expected to be Japan's fastest-growing source of renewable energy, increasing by 7.4 percent per year in the *IEO2009* reference case. Although wind power development is expected to continue, it has encountered difficulties because of limited government policy support and weather-related technological problems. Japan's current target for electricity from nonhydroelectric renewable sources is 1.63 percent by 2014, a relatively modest goal that is unlikely to encourage as much growth in Japan as in countries with more aggressive policies [**27**]. Inclement weather also has had a negative impact on wind development in Japan, with typhoons and lightning strikes damaging wind turbines and driving up the cost of wind farms in the country. Despite its current strategy of investing in research to develop J-Class wind turbines that can better withstand adverse weather conditions [**28**], wind remains a modest source of electric power for Japan in the *IEO2009* reference case, accounting for less than 1 percent of total electricity generation in 2030, as compared with hydropower's 8-percent share of the total in 2030.

Australia and New Zealand, as a region, rely on coal for about 70 percent of electricity generation, based largely on Australia's rich coal resource base (9 percent of the world's total coal reserves). The remaining regional generation is supplied by natural gas and renewable energy sources—mostly hydropower, wind, and, in New Zealand, geothermal. 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 2.9 percent per year from 2006 to 2030, reducing the coal share to 58 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, but despite a doubling of electricity generation from natural gas, its share of total generation increases only from 16 percent in 2006 to 19 percent in 2030. Coal and nuclear power continue to provide most of the South Korea's electricity generation, with a combined 77 percent of total electricity in 2030.

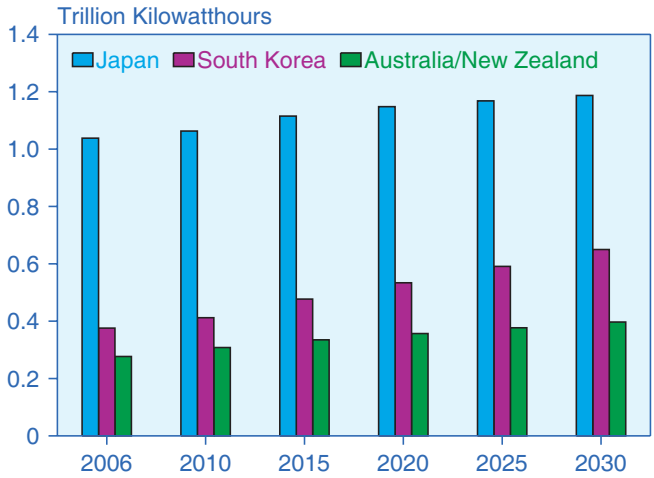
Non-OECD Economies

Non-OECD Europe and Eurasia

Total electricity generation in non-OECD Europe and Eurasia grows at an average rate of 2.0 percent per year in the *IEO2009* reference case, from 1.5 trillion kilowatthours in 2006 to 2.0 trillion kilowatthours in 2015 and 2.4 trillion kilowatthours in 2030. Russia, with the largest economy in non-OECD Europe and Eurasia, accounted for around 60 percent of the region's total generation in 2006 and is expected to retain approximately that share throughout the projection (Figure 57).

Natural gas and nuclear power are expected to supply much of the growth in electricity generation in the region. As a whole, non-OECD Europe and Eurasia has ample resources of natural gas, equal to nearly one-third of the world's total proved natural gas reserves. As a result, natural-gas-fired generation grows robustly in the outlook, by an average annual rate of 2.7 percent from 2006 to 2030.

Figure 56. Net Electricity Generation in OECD Asia, 2006-2030



Sources: **2006:** Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. **Projections:** EIA, World Energy Projections Plus (2009).

Generation from nuclear power also grows strongly in the region, averaging 2.8 percent per year. Much of the increase is expected in Russia. In 2006, the Russian government released Resolution 605, which set a federal target program for nuclear power development. The section of the resolution titled "Development of the Nuclear Industry in Russia 2007-2010 and -2015" states that 10 nuclear power reactors are to be completed by 2015: Volgodonsk 2, 3, and 4; Kalinin 4; Novoronezh 2-1 and 2-2; Leningrad 2-1, 2-2, and 2-3; and Beloyarsky 4 [***29***]. In addition, a total of 40 reactors are supposed to be constructed by 2030, raising Russia's nuclear generating capacity by 2 gigawatts per year from 2012 to 2014 and by 3 gigawatts per year from 2014 to 2020, bringing the total to 40 gigawatts [***30***] and increasing the nuclear share of total generation to 23 percent by 2020 [***31***]. The *IEO2009* 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 5 gigawatts of nuclear generating capacity is added to Russia's existing 23 gigawatts by 2015 and another 16 gigawatts by 2030.

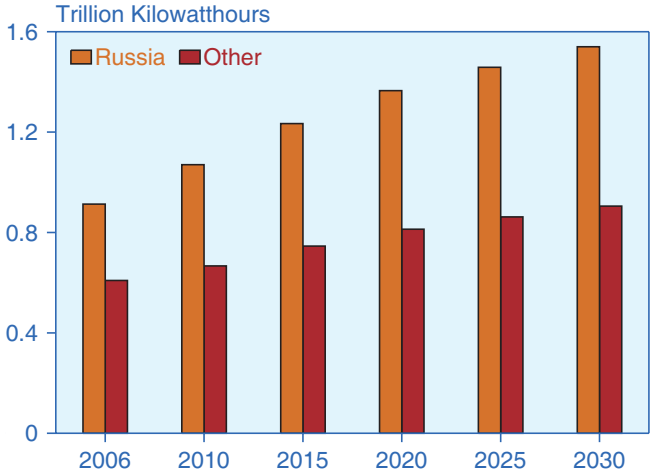
Renewable generation in non-OECD Europe and Eurasia, almost entirely from hydropower facilities, increases relatively slowly, by an average of 0.7 percent per year, largely as a result of repairs and expansions at existing sites. Notable exceptions include the 3,000-megawatt Boguchan Dam in Russia and the 3,600-megawatt Rogun Dam in Tajikistan [***32***]. Construction began on Boguchan in 1980 and on Rogun in 1976, but work ceased when the former Soviet Union experienced economic difficulties in the 1980s. Construction has recently been restarted on the Boguchan Dam, which is expected to be completed by 2012. Work on the Rogun Dam has been suspended but should begin again in the near term. Growth of nonhydropower renewable generation is projected to be negligible.

Non-OECD Asia

Non-OECD Asia—led by China and India—has the fastest projected regional growth in electric power generation worldwide, averaging 4.4 percent per year from 2006 to 2030 in the reference case. Although the global economic recession has an impact on the region's near-term economic growth, in the long term the economies of non-OECD Asia are expected to expand strongly, with corresponding increases in demand for electricity in both the building and industrial sectors. Total electricity generation in non-OECD Asia rises by nearly two-thirds between 2006 and 2015, from 4.4 trillion kilowatthours to 7.3 trillion kilowatthours. After 2015 the growth in electricity demand moderates as infrastructure matures and patterns of energy use in the regional economies begin to resemble those in the more established OECD nations. Still, electricity demand increases by 46 percent between 2015 and 2025, and by another 17 percent between 2025 and 2030. In 2030, net generation in non-OECD Asia totals 12.4 trillion kilowatthours in the reference case.

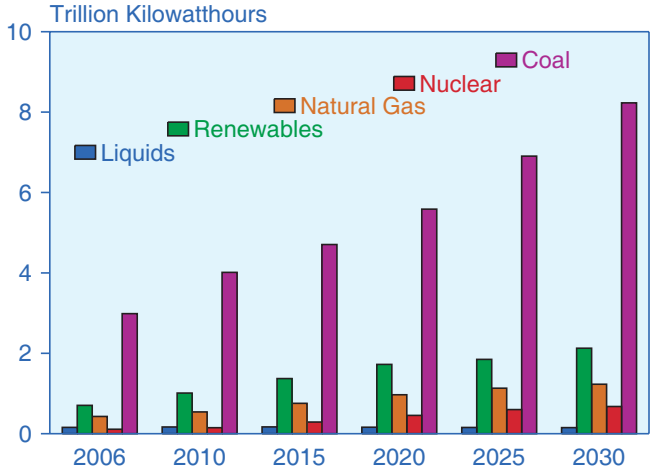
Coal accounts for two-thirds of the electricity generation in non-OECD Asia (Figure 58), dominated by generation in China and India. Both countries already rely heavily on coal to produce electric power. In 2006, coal's share of generation was an estimated 79 percent in China and 71 percent in India. Efforts to diversify the fuel mix away from coal are expected to meet with limited success, and it is likely that coal will remain the dominant source of

Figure 57. Net Electricity Generation in Non-OECD Europe and Eurasia, 2006-2030



Sources: **2006:** Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. **Projections:** EIA, World Energy Projections Plus (2009).

Figure 58. Net Electricity Generation in Non-OECD Asia by Fuel, 2006-2030



Sources: **2006:** Derived from Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. **Projections:** EIA, World Energy Projections Plus (2009).

power generation in both countries. In the *IEO2009* reference case, the coal share of electricity generation declines to 56 percent in India and 75 percent in China in 2030.

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 falls from 4 percent in 2006 to about 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 *IEO2009* reference case, accounting for 54 percent of the projected net increment in nuclear capacity worldwide (or 72 gigawatts of the total 132-gigawatt increase). China, in particular, has expansive plans for nuclear power, with a net 47 gigawatts of additional capacity projected to be installed by 2030. Currently, 11 nuclear power plants are under construction in China, including 6 for which construction was started in 2008 [***33***]. With generation from coal, natural gas, and renewable energy sources also expected to continue increasing rapidly, however, the nuclear share of total generation in China increases only from 2 percent in 2006 to 5 percent in 2030.

India also has plans to boost its nuclear power generation. From 3 gigawatts of installed nuclear power capacity in operation today, India has set an ambitious goal of increasing its nuclear generating capacity to 20 gigawatts by 2020 and 40 gigawatts by 2030 [***34***]. Six nuclear generating stations are under construction now, four of which are scheduled for completion by the end of 2009. There is considerable optimism for the future development of India's nuclear program, in part because of the "123 Agreement" signed by the United States and India in October 2008.[30] The agreement allows India—despite the fact it has not joined the Nuclear Non-Proliferation Treaty—to import nuclear materials, nuclear technology, and fuel [***35***]. The projected increase in nuclear capacity in the *IEO2009* reference case is somewhat slower than anticipated by India's government, with 17 gigawatts of net installed capacity becoming operational by 2030.

In addition to China and India, several other countries in non-OECD Asia are expected to begin or expand nuclear power programs. In the reference case, new nuclear power capacity is installed in Vietnam, Indonesia, and Pakistan by 2030. The impact of high fossil fuel prices, combined with concerns about security of energy supplies, leads many nations in the region to consider diversifying the fuel mix for their power generation by adding a nuclear component.

Electricity generation from renewable energy sources in non-OECD Asia is projected to grow at an average annual rate of 4.7 percent, increasing the renewable share of the region's total generation from 16 percent in 2006 to 17 percent in 2030. Mid- to large-scale hydroelectric facilities provide much of the increment. Several countries have hydropower facilities either planned or under construction, including Vietnam, Malaysia, Pakistan, and Myanmar (the former Burma). Almost 50 hydropower facilities, with a combined 3,398 megawatts of capacity, are under construction in Vietnam's Son La province, including the 2,400-megawatt Son La and 520-megawatt Houi Quang projects, both of which are scheduled for completion before 2015 [***36***]. Malaysia expects to complete its 2,400-megawatt Bakun Dam by 2011, although the project has experienced a number of delays and setbacks in the past [***37***]. Pakistan and Myanmar also have substantial hydropower development plans, but those plans have been discounted in the *IEO2009* reference case to reflect the two countries' historical difficulties in acquiring foreign direct investment for infrastructure projects.

India has plans to more than double its installed hydropower capacity by 2030. In its Eleventh and Twelfth Five-Year Plans, which span 2007 through 2017, India's Central Electricity Authority has identified 40,943 megawatts of hydroelectric capacity that it intends to build. Although the *IEO2009* reference case does not assume that all the planned capacity will be completed, more than one-third of the announced projects are under construction already and are expected to be completed by 2020 [***38***].

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 and allow generators to improve their returns by selling up to 40 percent of their electricity on the spot market. In addition, India's federal hydropower intentions are being supported by state authorities. The state government in 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, which would nearly double the existing capacity [***39***]. Also, the 2,000-megawatt lower Subansiri facility under construction in Arunachal Pradesh is expected to be completed by 2012 [***40***].

[30] The United States has negotiated 123 agreements with several countries. The agreements are part of the U.S. Atomic Energy Act of 1954, which promotes the peaceful pursuit of nuclear power among nations.

Similar to India, China also has a number of large-scale hydroelectric projects under construction. The 18,200-megawatt Three Gorges Dam project's final generator went on line in October 2008, and the Three Gorges Project Development Corporation plans to further increase the project's total installed capacity to 22,400 megawatts by 2012 [*41*]. 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). The country's third-largest hydroelectric facility, the 6,300-megawatt Longtan project on the Hongshui River, is scheduled for completion before the end of 2009 [*42*]. 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 [*43*].

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 plans for 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 [*44*]. The Chinese government has set a 300-gigawatt target for hydroelectric capacity in 2020. Including those mentioned above, the country has a sufficient number of projects under construction or in development to meet the target. China's aggressive hydropower development plan is expected to increase hydroelectricity generation by 4.0 percent per year, more than doubling the country's total hydroelectricity generation by 2030.

Although hydroelectric projects dominate the renewable energy mix in non-OECD Asia, generation from nonhydroelectric renewable energy sources, especially wind, also is expected to grow significantly. At the end of 2008, China completed installation of its 10,000th megawatt of wind capacity, achieving its 2010 target a full year ahead of the schedule set out by the National Development and Reform Commission [*45*]. The Chinese government has established a 30,000-megawatt target for installed wind capacity by 2020; however, at the current installation rate of at least 3,000 megawatts of wind capacity a year, China is projected to have 40,000 megawatts of wind capacity installed by 2020. The *IEO2009* reference case anticipates that electricity from wind plants in China will grow by 23.2 percent per year, from 2 billion kilowatthours in 2006 to 315 billion kilowatthours in 2030.

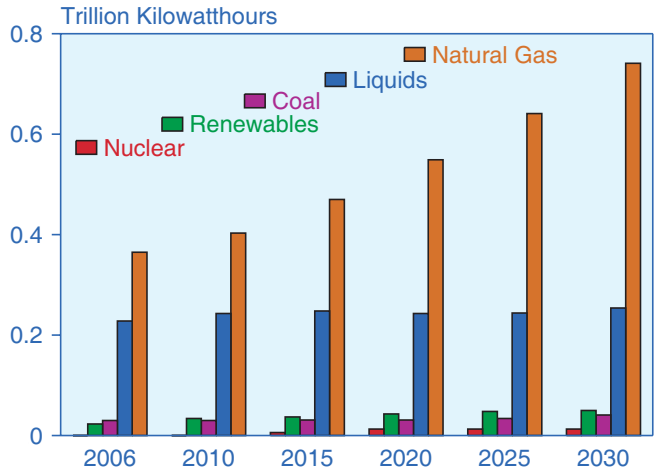
Geothermal energy, while a small contributor to non-OECD Asia's total electricity generation, plays an important role in the Philippines and Indonesia. With the second-largest amount of installed geothermal capacity in the world, the Philippines generated more than 17 percent of its total electricity from geothermal sources in 2007 [*46*]. Indonesia, with the fifth-largest installed geothermal capacity, generated just over 5 percent of its electricity from geothermal energy in 2005, the last year for which reliable data are available [*47*]. Although the Indonesian geothermal industry suffered setbacks from the country's 1997 financial crisis, there is strong potential for future geothermal development, with more than 20 gigawatts of geothermal potential available [*48*]. Both the Philippines and Indonesia have announced plans to increase their installed geothermal capacities in the coming years.

Middle East

Electricity generation in the Middle East region grows by 2.2 percent per year in the reference case, from 0.6 trillion kilowatthours in 2006 to 1.1 trillion kilowatthours in 2030. The region's young and rapidly growing population and an expected strong increase in national income are expected to result in rapid growth in demand for electric power. Iran, Saudi Arabia, and the United Arab Emirates (UAE) account for two-thirds of the regional demand for electricity, and demand has increased sharply over the past several years in each of the countries. From 2000 to 2006, Iran's net generation increased by an average of 9.1 percent per year; Saudi Arabia's by 6.1 percent per year; and the UAE's by 8.9 percent per year.

The Middle East depends on natural gas and petroleum liquids to generate most of its electricity and is projected to continue that reliance through 2030 (Figure 59). In

Figure 59. Net Electricity Generation in the Middle East by Fuel, 2006-2030



Sources: **2006:** Derived from Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. **Projections:** EIA, World Energy Projections Plus (2009).

2006, natural gas supplied 56 percent of electricity generation in the Middle East and liquids 35 percent. In 2030, the natural gas share is projected to be 67 percent and the liquids share 23 percent. There has been a concerted effort by many of the petroleum exporters in the region to develop their natural gas resources for use in domestic power generation. Petroleum is a valuable export commodity for many nations in 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.

Given the collapse of world oil prices at the end of 2008, oil-fired generation in the Middle East is likely to increase in the short-run, particularly in major oil-exporting nations that rely on associated natural gas production to fulfill growing demand for natural gas in the power sector. In Saudi Arabia, for instance, associated natural gas from oil production accounts for 60 percent of total natural gas supply [***49***]. As Saudi oil production has been reduced both as a reaction to the lowered worldwide demand for liquids and in an attempt to stabilize oil prices, the associated natural gas production has slowed as well. Until world oil prices and demand recover from current lows and production of both oil and natural gas begins to rise, petroleum is likely to continue being used to supplement natural gas in the power sector. In the *IEO2009* reference case, liquids-fired generation in the Middle East grows from 228 billion kilowatthours in 2006 to 248 billion kilowatthours in 2015 and 254 billion kilowatthours in 2030.

Other energy sources make only minor contributions to electricity supply in the Middle East. Israel is the only country in the region that uses significant amounts of coal to generate electric power [***50***], and Iran, with the completion of its Bushehr 1 reactor expected in 2011, is the only one projected to add nuclear capacity. Other Middle Eastern countries recently have expressed some interest in increasing both coal-fired and nuclear generation, however, in response to concerns about diversifying the electricity fuel mix and meeting the region's fast-paced growth in electricity demand. For example, Oman announced in 2008 that it would construct the Persian Gulf's first coal-fired power plant at Duqm [***51***]. Although details have not been released, it is expected that the plant—if constructed—would have a capacity between 1,000 and 2,000 megawatts and could be completed as early as 2012. The UAE, Saudi Arabia, and Bahrain also have considered adding coal-fired capacity [***52***].

In addition to Iran, several other Middle Eastern nations have announced intentions to pursue nuclear power programs in recent years. In 2007, the six-nation Gulf Cooperation Council[31] completed a feasibility study, in cooperation with the International Atomic Energy Association, of the potential for a regional nuclear power and desalinization program, while also announcing their intention to pursue a peaceful nuclear program [***53***]. The UAE government in 2008 announced plans to have three 1,500-megawatt nuclear power plants completed by 2020 and has since signed nuclear cooperative agreements with France, Japan, the United Kingdom, and the United States [***54***]. Jordan also has announced its intention to add nuclear capacity [***55***], and in 2009 the Kuwaiti cabinet announced that it would form a national committee on nuclear energy use for peaceful purposes [***56***]. Even given the considerable interest in nuclear power that has arisen in the region, however, *IEO2009* expects that economic and political issues, in concert with the long lead times usually associated with beginning a nuclear program, will mean that beyond Iran's Bushehr 1 reactor, only the UAE will add one additional nuclear power plant in the Middle East over the course of the projection.

Although there is little incentive for countries in the Middle East to increase their use of renewable energy sources (the renewable share of the region's total electricity generation increases only from 4 percent in 2006 to 5 percent in 2030 in the reference case), there have been some recent developments in renewable energy use in the region. Iran, which generated 9 percent of its electricity from hydropower in 2006, is developing 94 new hydroelectric power plants, 5 of which are expected to come on line before March 2010 [***57***]. Construction also continues on Masdar City in Abu Dhabi, a "zero carbon" city that will be powered by 190 megawatts of solar photovoltaic cells and 20 megawatts of wind power [***58***]. The first phase of construction is expected to be completed by the end of 2009.

Africa

Demand for electricity in Africa grows at an average annual rate of 2.6 percent in the *IEO2009* reference case. Fossil-fuel-fired generation supplied 81 percent of the region's total electricity in 2006, and reliance on fossil fuels is expected to continue through 2030. Coal-fired power plants, which were the region's largest source of electricity in 2006, accounting for 46 percent of total generation, are projected to provide a 37-percent share in 2030, and natural-gas-fired generation is projected to expand strongly, from 25 percent of the total in 2006 to 39 percent in 2030 (Figure 60).

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 could begin in South Africa in 2010, with an anticipated completion date of 2014; however, the

[31] Gulf Cooperation Council members are Saudi Arabia, Kuwait, Bahrain, the United Arab Emirates, Qatar, and Oman.

project has had various setbacks since it was originally initiated in 1993, and it is uncertain whether the current schedule will be met [*59*]. In addition, Egypt's government has moved forward with its plans to construct a nuclear power project, signing a nuclear power cooperation agreement with Russia in 2008 and awarding a contract to U.S.-based Bechtel to design the new power plant, tentatively to be located at Dabaa, about 100 miles west of Alexandria [*60*]. In the reference case, 1,100 megawatts of net nuclear capacity is projected to become operational in Africa over the 2006-2030 period, and the nuclear share of the region's total generation remains at 2 percent through the end of the period.

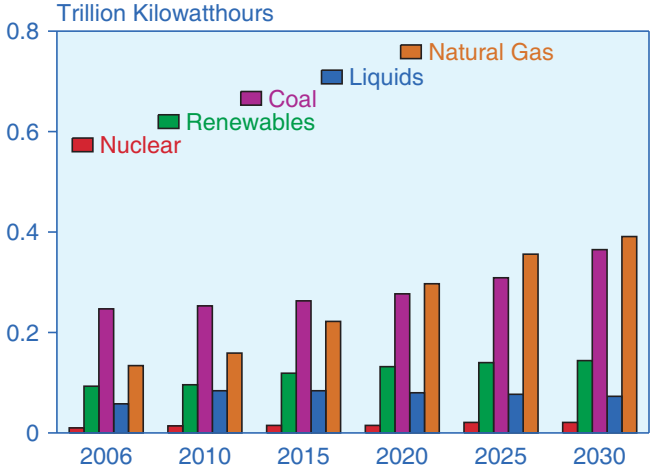
Generation from hydropower and other marketed renewable energy sources is expected to grow slowly in Africa. As they have in the past, nonmarketed renewables are expected to continue providing energy to Africa's rural areas; however, it is often difficult for African nations to find funding or international support for larger commercial projects. Plans for several hydroelectric projects in the region have been advanced recently, however, 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 1.8 percent per year from 2006 to 2030. For example, Ethiopia is finishing work on three hydroelectric facilities: the 300-megawatt Takeze power station, the 460-megawatt Anabeles, and the 420-megawatt Gilgel Gibe II, all of which are scheduled for completion at the end of 2009 [*61*].

Central and South America

Electricity generation in Central and South America increases by 2.2 percent per year in the *IEO2009* reference case, from 0.9 trillion kilowatthours in 2006 to 1.2 trillion kilowatthours in 2015 and 1.6 trillion kilowatthours in 2030. The present global economic crisis is affecting the region's economies and thus their electricity markets, lowering demand for electricity, especially in the industrial sector. In the longer term, however, the region's electricity markets are expected to return to trend growth as the economic difficulties recede.

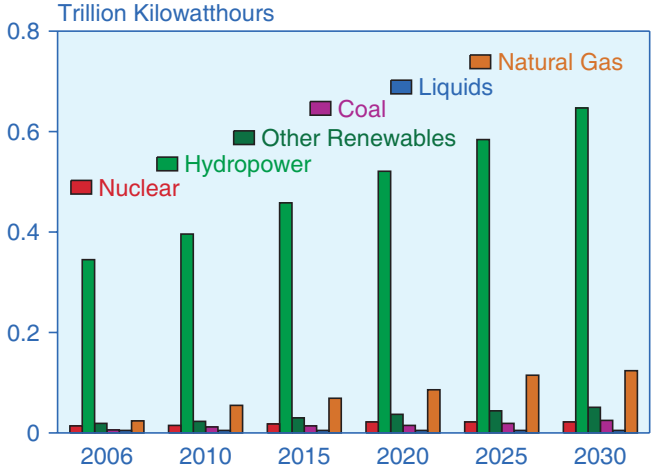
The fuel mix for electricity generation in Central and South America is dominated by hydroelectric power, which accounted for two-thirds of the region's total net electricity generation in 2006. Of the top seven electricity generating countries in the region, six generate more than 55 percent of their total electricity from hydropower—Brazil, Venezuela, Paraguay, Colombia, Chile, and Peru.[32] In Brazil, the region's largest economy, hydropower provided almost 84 percent of electricity generation in 2006 (Figure 61). The country has been trying to diversify its electricity supply fuel mix away from hydroelectric power because of the risk of power shortages during times of severe drought. In the Brazilian National Energy Plan for 2008-2017, the government has set a goal to reduce reliance on hydropower to 78 percent [*62*]. To achieve that target, the government has announced plans to increase nuclear power capacity, beginning with the completion of the long-idled 1,000-megawatt Angra-3 project [*63*]. Construction is set to begin in April 2009, and the reactor is scheduled to begin coming on line in 2014. Brazil also has plans to

Figure 60. Net Electricity Generation in Africa by Fuel, 2006-2030



Sources: **2006:** Derived from Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. **Projections:** EIA, World Energy Projections Plus (2009).

Figure 61. Net Electricity Generation in Brazil by Fuel, 2006-2030



Sources: **2006:** Derived from Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. **Projections:** EIA, World Energy Projections Plus (2009).

[32] Argentina is the region's second-largest electricity generator but derives only about one-third of its electricity from hydropower.

construct four additional 1,000-megawatt nuclear plants beginning in 2015. In the *IEO2009* reference case, only the Anagra-3 project is projected to be completed by 2015, and none of the other planned nuclear projects in Brazil is expected to be completed before 2030.

In the past, the Brazilian government has tried relatively unsuccessfully to attract substantial investment in natural-gas-fired power plants, mostly because of the higher costs of natural-gas-fired generation relative to hydroelectric power and because of concerns about the security of natural gas supplies. Brazil has relied on imported Bolivian natural gas for much of its supply, but concerns about the impact of Bolivia's nationalization of its energy sector on foreign investment in the country's natural gas production has led Brazil to look toward LNG imports for secure supplies. Brazil has invested strongly in its LNG infrastructure, and its third LNG regasification plant is scheduled for completion in 2013 [***64***]. With Brazil diversifying its natural gas supplies, substantially increasing domestic production, and resolving to reduce the hydroelectric share of generation, natural gas is projected to be its fastest-growing source of electricity, increasing by 7.1 percent per year on average from 2006 to 2030.

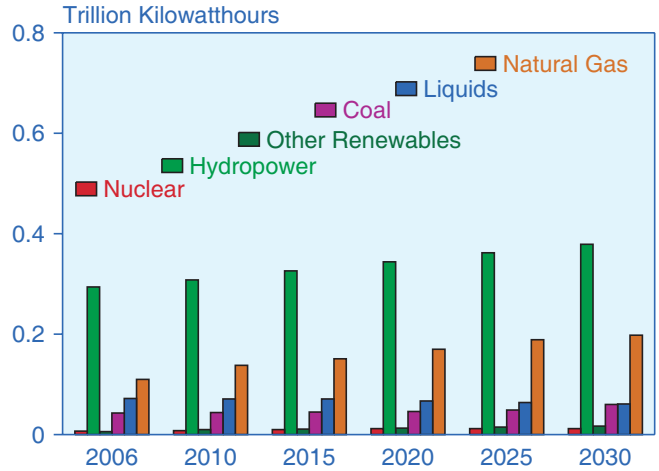
Several other nations in Central and South America have been trying to increase the amounts of natural gas used in their generation fuel mixes by increasing both pipeline and LNG supplies. Chile, for instance, relies on Argentina for its natural gas supplies, but beginning in 2004, Argentina began to restrict its exports after it was unable to meet its own domestic supply. As a result, Chile has been forced to use diesel-fueled electric generating capacity periodically to avoid power outages during the winter months [***65***]. In response to the lack of a secure source of natural gas from Argentina, Chile has begun construction on two LNG regasification projects. The Quintero facility is expected to become operational in June 2009, and the second Mejillones facility scheduled for completion by the end of 2010. In the *IEO2009* reference case, natural-gas-fired generation in Central and South America (excluding Brazil) increases by an average 2.5 percent per year, and the natural gas share of total electricity generation rises from 21 percent in 2006 to 27 percent in 2030 (Figure 62).

Brazil still has plans to continue expanding its hydroelectric generation over the projection period, including the construction of 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 2012-2015, are expected to help Brazil meet electricity demand in the mid-term [***66***]. In the long term, electricity demand could be met in part by the 11,181-megawatt Belo Monte dam, which is scheduled to receive bids for construction in 2009; however, each of the three projects could be subject to delay as a result of legal challenges. An injunction to stop the construction of the Jirau power plant, for example, was overturned in 2008 after the plaintiff's second appeal [***67***].

Brazil also is interested in increasing the use of other, nonhydroelectric renewable resources in the future—notably, wind. Wind power generation in Brazil grows by 14.8 percent per year in the *IEO2009* reference case, from 250 million kilowatthours in 2006 to 6,890 million kilowatthours in 2030. Despite that robust growth projection, however, wind remains a modest component of Brazil's renewable energy mix in the reference case, as compared with the projected growth in hydroelectric generation to 646,600 million kilowatthours in 2030.

Increases in Brazil's electricity generation from nonhydropower renewable energy sources have been supported primarily by the federal Program of Incentives for Alternative Electricity Sources (PROINFA). Phase I of the program guaranteed power purchase agreements for 3,300 megawatts of biomass, wind, and small hydroelectric capacity through 2008. A second phase of PROINFA was intended to increase nonhydroelectric generation to 10 percent of total electricity generation by 2027, but insufficient utilization of Phase I has reduced the likelihood that Phase II will be implemented [***68***]. Until a replacement policy is enacted, growth in Brazil's nonhydroelectric renewable generation is expected to be relatively slow in comparison with the growth in other sources of electricity generation.

Figure 62. Net Electricity Generation in Other Central and South America by Fuel, 2006-2030



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