Chapter 5

Electricity

Overview

In the *International Energy Outlook 2016* (IEO2016) Reference case, world net electricity generation increases 69% by 2040, from 21.6 trillion kilowatthours (kWh) in 2012 to 25.8 trillion kWh in 2020 and 36.5 trillion kWh in 2040. Electricity is the world's fastest-growing form of end-use energy consumption, as it has been for many decades. Power systems have continued to evolve from isolated, small grids to integrated national markets and even international markets.

Economic growth is an important factor in electricity demand growth. Although world gross domestic product (GDP) growth slows in the IEO2016 Reference case in comparison with the past two decades, electricity demand continues to increase, especially among the emerging non-Organization for Economic Cooperation and Development (non-OECD) economies. In 2012, electricity generation in non-OECD countries represented slightly more than one-half of world electricity demand. With continued strong economic growth, the non-OECD share of world electricity generation increases to 61% in 2040 (Figure 5-1), as total non-OECD electricity generation nearly doubles, from 11.3 trillion kWh in 2012 to 22.3 trillion kWh in 2040 (Table 5-1).

In general, the projected growth of electricity demand in OECD countries, where electricity markets are well established and electricity consumption patterns are mature, is slower than in the non-OECD countries. OECD GDP increases by 2.0%/year, less than half the 4.2%/year GDP growth projected for non-OECD countries. OECD net electricity generation increases by 38%, from 10.2 trillion kWh in 2012 to 14.2 trillion kWh in 2040.

The IEO2016 Reference case projections reflect the expectation that economic activity will continue to drive electricity demand growth; however, the rate of growth in electricity consumption continues to become smaller compared to the rate of growth in GDP. From 2005 to 2012, world GDP increased by 3.7%/year, while world net electricity generation rose by 3.2%/year. In many parts of the world, policy actions aimed at improving efficiency will help to decouple economic growth rates and electricity demand growth rates more in the future (Figure 5-2). In the IEO2016 Reference case, world GDP grows by 3.3%/year, and world net electricity generation grows by 1.9%/year, from 2012 to 2040. The 69% increase in world electricity generation through 2040 is far below what it would be if economic growth and electricity demand growth maintained the same relationship they had in the recent past.

Many countries, particularly among the developed OECD nations are pursuing policies and regulations intended to increase the pressure on generators to reduce greenhouse gas emissions from electric power plants by decreasing the use of fossil fuels. As a result, the role of coal as a dominant fuel for electric power plants is being reduced. Since the last forecast cycle, there have been significant revisions to national clean energy policies to reduce emissions, including China's target of 15% renewable electricity by 2020,[164] the European Union's 2030 Energy Framework objectives,[165] and India's megawatts-to-gigawatts renewable energy commitment.[166] The IEO2016 Reference case analysis incorporates many updated targets that reflect the revised regulations

Figure 5-1. OECD and non-OECD net electricity generation, 1990–2040 (trillion kilowatthours)

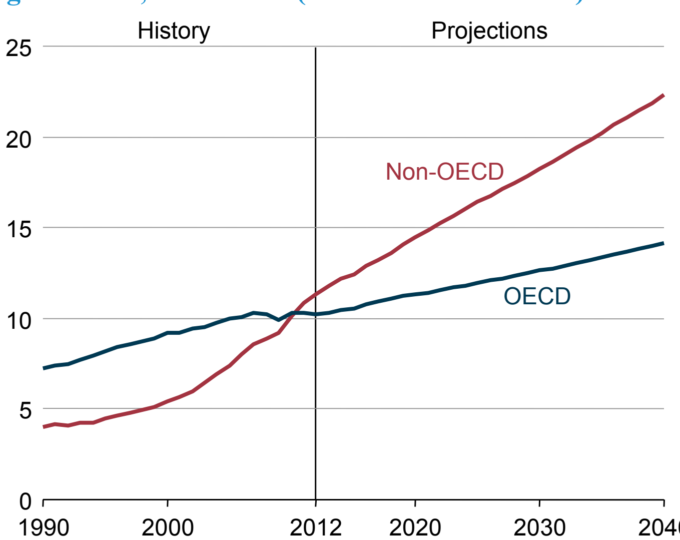
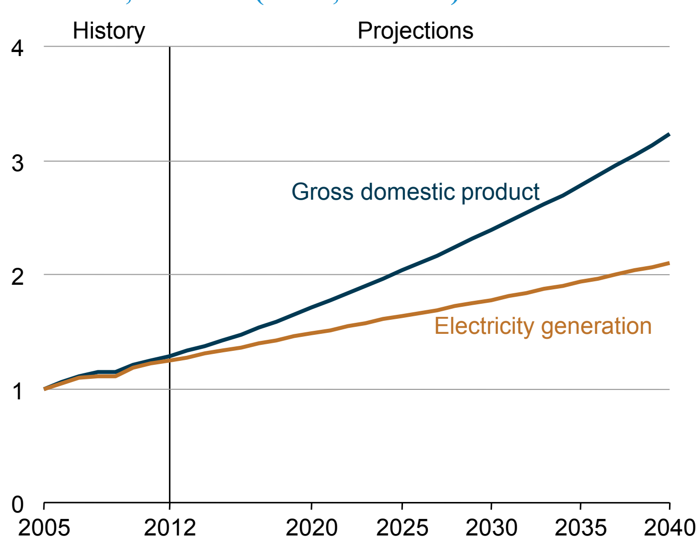


Figure 5-2. Growth in world electricity generation and GDP, 2005–40 (index, 2005 = 1)



[164] World Resources Institute, "Renewable Energy in China: An Overview" (Washington, DC: May 13, 2014), http://www.chinafaqs.org/files/chinainfo/ChinaFAQs_Renewable_Energy_Overview_0.pdf.

[165] European Commission, "2030 climate & energy framework" (December 10, 2015), http://ec.europa.eu/clima/policies/strategies/2030/index_en.htm.

[166] "India graduating from megawatts to gigawatts in renewable energy: Modi," newKerala.com (February 16, 2015), http://www.newkerala.com/news/2015/fullnews-19800.html.

and national energy policies that affect renewable energy. *(See later sections for region- or fuel-specific revisions.)* The effect of the recently finalized Clean Power Plan (CPP) regulations in the United States is not included in the IEO2016 Reference case, but its effects are considered in discussions, tables, and figures throughout the report, based on U.S. Energy Information Administration (EIA) analysis of the proposed rule, which had similar elements.

Given the recent history of renewable energy policy and the scale of current commitments, EIA evaluated the probability that stated targets would be met, based on: (1) data on the countries' prior success in meeting renewable policy objectives, accounting for both the ambition and extent of fulfillment of targets; (2) indicators of the countries' financial capability to build new projects; and (3) assessments of market pricing to support renewable energy sources. EIA adjusted the probabilities associated with successful implementation, with declining expectations dependent on how far into the future the target was specified.

The IEO2016 Reference case also reflects the impacts of broader policies to constrain energy-related carbon dioxide (CO2) emissions in emerging market countries, such as China and India. In those countries, policymakers have proposed a range of programs that place particular emphasis on the countries' Intended Nationally Determined Contributions (INDCs) for addressing CO2 emissions reductions as part of the 21st Conference of Parties (COP21) meetings[167] held in Paris from November 30 to December 11, 2015. In instances where the objective is clear but specific policy mechanisms are not yet known, judgment was applied to determine the likelihood that the intended outcomes would be achieved without attempting to predict specific actions. New and unanticipated government policies or legislation aimed at limiting or reducing greenhouse gas or other power-sector emissions, which could substantially change the trajectories of fossil and nonfossil fuel consumption, were not incorporated in the IEO2016 Reference case.

Table 5-1. OECD and non-OECD net electricity generation by energy source, 2012–40 (trillion kilowatthours)

Energy source by region	2012	2020	2025	2030	2035	2040	Average annual percent change, 2012–40
OECD	**10.2**	**11.3**	**12.0**	**12.6**	**13.3**	**14.2**	**1.2**
Petroleum and other liquids	0.4	0.2	0.1	0.1	0.1	0.1	-4.1
Natural gas	2.6	2.6	3.0	3.5	4.0	4.5	2.0
Coal	3.2	3.4	3.4	3.3	3.3	3.3	0.0
Nuclear	1.9	2.1	2.2	2.3	2.3	2.2	0.7
Renewables	2.2	3.0	3.2	3.4	3.7	4.0	2.2
OECD with CPP	**10.2**	**11.3**	**11.8**	**12.5**	**13.2**	**14.0**	**1.1**
Petroleum and other liquids	0.4	0.2	0.1	0.1	0.1	0.1	-4.2
Natural gas	2.6	2.9	3.1	3.5	3.9	4.4	1.9
Coal	3.2	3.0	2.8	2.8	2.8	2.8	-0.5
Nuclear	1.9	2.1	2.2	2.3	2.3	2.2	0.6
Renewables	**2.2**	**3.0**	**3.6**	**3.8**	**4.1**	**4.4**	**2.6**
Non-OECD	**11.3**	**14.4**	**16.4**	**18.2**	**20.2**	**22.3**	**2.5**
Petroleum and other liquids	0.7	0.6	0.6	0.5	0.5	0.5	-1.5
Natural gas	2.2	2.6	3.3	4.0	4.8	5.6	3.4
Coal	5.4	6.3	6.7	6.8	7.0	7.3	1.1
Nuclear	0.5	0.9	1.2	1.7	2.0	2.3	5.7
Renewables	2.6	3.9	4.7	5.3	6.0	6.6	3.5
Total World	**21.6**	**25.8**	**28.4**	**30.8**	**33.6**	**36.5**	**1.9**
Petroleum and other liquids	1.1	0.9	0.7	0.6	0.6	0.6	-2.2
Natural gas	4.8	5.3	6.3	7.5	8.8	10.1	2.7
Coal	8.6	9.7	10.1	10.1	10.3	10.6	0.8
Nuclear	2.3	3.1	3.4	3.9	4.3	4.5	2.4
Renewables	4.7	6.9	7.9	8.7	9.6	10.6	2.9
Total World with CPP	**21.6**	**25.7**	**28.2**	**30.7**	**33.5**	**36.3**	**1.9**
Petroleum and other liquids	1.1	0.9	0.7	0.6	0.6	0.6	-2.2
Natural gas	4.8	5.5	6.4	7.5	8.8	10.0	2.6
Coal	8.6	9.4	9.5	9.6	9.8	10.2	0.6
Nuclear	2.3	3.1	3.4	3.9	4.2	4.5	2.3
Renewables	4.7	6.9	8.3	9.1	10.1	11.1	3.1

[167] International Institute for Sustainable Development, "Climate Change Policy & Practice" (undated), http://climate-l.iisd.org/events/unfccc-cop-21/.

The national policies represented in the IEO2016 Reference case interact with technology and fuel costs to result in a significant shift in the primary fuels used to generate electricity. Since the late 1980s, coal has consistently met 37% to 40% of world fuel requirements for electricity generation.[168] In the IEO2016 Reference case, the coal share of total generation declines from 40% in 2012 to 29% in 2040, even as world coal-fired generation increases by 25% through 2040. At the same time, the shares of total generation for both renewable energy sources and natural gas expand: from 22% in 2012 to 29% in 2040 for renewables and from 22% in 2012 to 28% in 2040 for natural gas (Figure 5-3).

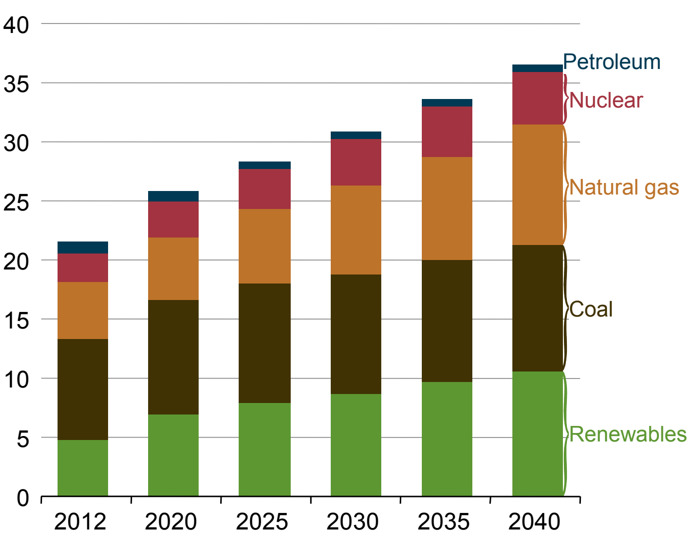
Electricity generation by source

The worldwide mix of primary fuels used to generate electricity has changed a great deal over the past several decades. Coal continues to be the fuel most widely used in electricity generation,[169] but there have been significant shifts to other generation fuels. Generation from nuclear power increased rapidly from the 1970s through the 1980s, and natural gas-fired generation increased considerably after the 1980s. The use of oil for generation declined after the late 1970s, when sharp increases in oil prices encouraged power generators to substitute other energy sources for oil.[170]

Beginning in the early 2000s, concerns about the environmental consequences of greenhouse gas emissions heightened interest in the development of renewable energy sources, as well as natural gas—a fossil fuel that emits significantly less CO2 than either oil or coal per kilowatthour generated. In the IEO2016 Reference case, long-term global prospects continue to improve for generation from natural gas, nuclear, and renewable energy sources. Renewables are the fastest-growing source of energy for electricity generation, with annual increases averaging 2.9% from 2012 to 2040. In particular, in the Reference case, nonhydropower renewable resources are the fastest-growing energy sources for new generation capacity in both the OECD and non-OECD regions. Nonhydropower renewables accounted for 5% of total world electricity generation in 2012; their share in 2040 is 14% in the IEO2016 Reference case, with much of the growth coming from wind power.

After renewable energy sources, natural gas and nuclear power are the next fastest-growing sources of electricity generation. From 2012 to 2040, natural gas-fired electricity generation increases by 2.7%/year and nuclear power generation increases by 2.4%/year. With coal-fired generation growing by only 0.8%/year, renewable generation (including both hydropower and nonhydropower resources) overtakes coal to become the world's largest source of energy for electricity generation by 2040. The outlook for coal-fired electricity generation could be further altered in the future by additional national policies or international agreements aimed at reducing or limiting its use. It should be noted that the IEO2016 Reference case does not include implementation of the U.S. Clean Power Plan, which would reduce the use of coal in the United States substantially *(see "U.S. Clean Power Plan Rule" in the Emissions chapter)*. Finally, if other nations with shale gas resources (notably, China) are able to replicate the U.S. success in exploiting shale gas production, the outlook for world natural gas-fired electricity generation could be much different from that represented in the IEO2016 Reference case.

Figure 5-3. World net electricity generation by fuel, 2012–40 (trillion kilowatthours)



Coal

Coal continues to be the largest single fuel used for electricity generation worldwide in the IEO2016 Reference case until the end of the projection period, with renewable generation beginning to surpass coal-fired generation in 2040. Coal-fired generation, which accounted for 40% of total world electricity generation in 2012, declines to 29% of the total in 2040 in the Reference case, despite a continued increase in total coal-fired electricity generation from 8.6 trillion kWh in 2012 to 9.7 trillion kWh in 2020 and 10.6 trillion kWh in 2040. Total electricity generation from coal in 2040 is 23% above the 2012 total.

China and India alone account for 69% of the projected worldwide increase in coal-fired generation, while the OECD nations continue to reduce their reliance on coal-fired electricity generation. With implementation of the Clean Power Plan, projections for U.S. coal-fired generation are reduced in 2030 by about one-third.

[168] International Energy Agency, "Coal statistics" (undated), http://www.iea.org/statistics/topics/coal/.

[169] Excluding the impact of the Clean Power Plan in the United States, which would reduce overall growth by roughly 560 billion kWh, or about 5%, by 2030 according to the EIA report, *Analysis of the Impacts of the Clean Power Plan* (Washington, DC: May 2015), https://www.eia.gov/analysis/requests/powerplants/cleanplan/.

[170] International Energy Agency, "Energy Balances of OECD Countries" (2013), and "Energy Balances of Non-OECD Countries" (2013), http://www.iea.org/statistics/onlinedataservice/ (subscription site).

Natural gas

Worldwide natural gas consumption for electricity generation grows in the IEO2016 Reference case by an average of 2.7%/year from 2012 to 2040. From 22% of total world electricity generation in 2012, the natural gas share increases to 28% in 2040 in the IEO2016 Reference case. In the United States, natural gas-fired generation is encouraged by low prices and favorable greenhouse gas emission characteristics. Natural gas is the least carbon-intensive fossil fuel; like all fossil fuels, natural gas combustion emits carbon dioxide, but at about half the rate of coal. In addition, natural gas generation technologies are more efficient than coal generation in producing electricity. Thus, natural gas can help in meeting CO2 reduction goals for many countries.

Petroleum and other liquid fuels

The use of petroleum and other liquid fuels for electricity generation continues to decline steadily in the IEO2016 Reference case. The share of total world generation from liquid fuels falls from 5% in 2012 to 2% in 2040, an average decline of 2.2%/year. Despite their recent decline, oil prices are expected to be higher in the long-term projection. As a result, liquids remain a more expensive option compared to other fuels used for generating electricity, and generators replace liquids-fired generation with other fuels where possible. Since June 2014, world oil prices have decreased substantially, falling to less than $40 per barrel in December 2015—a level last observed in late 2008, during the worldwide economic recession. The most notable regional declines in petroleum use for electricity generation are projected for the Middle East, Mexico, and Japan, where policy movements have encouraged the phasing out of oil in the electric power sector.

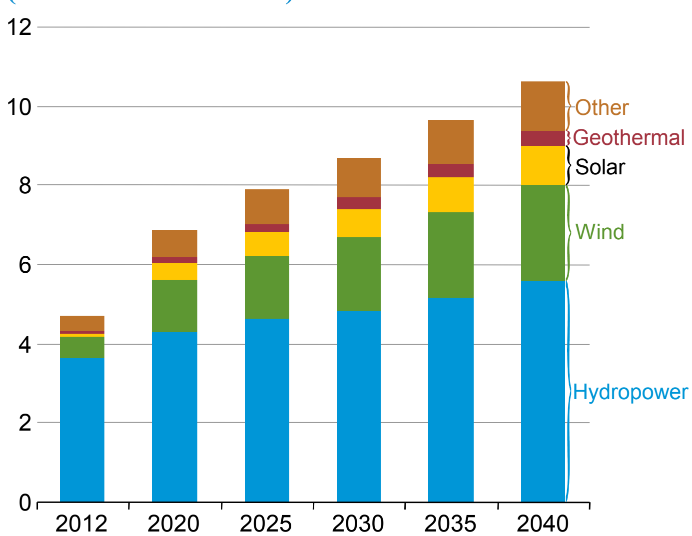
Renewable resources

Renewables account for a rising share of the world's total electricity supply, and they are the fastest growing source of electricity generation in the IEO2016 Reference case (Figure 5-4). Total generation from renewable resources increases by 2.9%/year, as the renewable share of world electricity generation grows from 22% in 2012 to 29% in 2040 (Table 5-2). Generation from nonhydropower renewables is the predominant source of the increase, rising by an average of 5.7%/year and outpacing increases in natural gas (2.7%/year), nuclear (2.4%/year), and coal (0.8%/year), even without taking into account the growth in renewable generation anticipated under the Clean Power Plan in the United States. By 2030, the CPP would increase U.S. renewables generation by roughly 396 billion kWh (58%) compared to the IEO2016 Reference case, according to EIA's analysis of the proposed CPP rule. Solar is the world's fastest-growing form of renewable energy, with net solar generation increasing by an average of 8.3%/year. Of the 5.9 trillion kWh of new renewable generation added over the projection period, hydroelectric and wind each account for 1.9 trillion kWh (33%), solar energy for 859 billion kWh (15%), and other renewables (mostly biomass and waste) for 856 billion kWh (14%).

In the IEO2016 Reference case, the pattern of growth in renewable electricity generation differs between the OECD regions and non-OECD regions in two ways: the relative rates of increase in generation from nonhydropower renewables and the potential expansion of hydropower capacity. Non-OECD countries surpass OECD countries in their use of nonhydropower renewables for electricity generation by the end of the projection in 2040. OECD net generation from nonhydropower renewables totals 2.3 trillion kWh (or 2.7 trillion kWh with the U.S. Clean Power Plan), compared with the non-OECD total of 2.8 trillion kWh. The difference is primarily the result of ambitious solar targets adopted principally by India and China, and to some extent by other emerging market countries *(see "World production of solar photovoltaic modules," below)*. In the non-OECD region as a whole, solar generation grows by 15.7%/year on average from 2012 to 2040, nearly twice the growth rates for wind (7.7%/year) and geothermal (8.6%/year). In the OECD region, by comparison, wind, solar, and geothermal generation grow at comparable rates of about 4.5%/year.

Even with the projected strong growth of electricity generation from nonhydropower renewable energy sources in the non-OECD region, hydropower remains an important source of growth in the region's renewable energy use. Non-OECD hydropower generation increases by 71% from 2012 to 2040, accounting for almost 40% of the total increase in non-OECD renewable electricity generation over the period. The world's fastest regional growth in hydroelectric generation is projected for non-OECD Asia *(see "Plans for hydroelectric generation capacity additions in Southeast Asia," below)*. Hydroelectricity production in non-OECD Asia increases by 2.2%/year on average from 2012 to 2040.

Figure 5-4. World net electricity generation from renewable power by fuel, 2012–40 (trillion kilowatthours)



Note: Other generation includes biomass, waste, and tide/wave/ocean.

World production of solar photovoltaic modules

Growth in solar photovoltaic (PV) manufacturing production and the expansion of manufacturing capability have slowed in recent years. From 2006 to 2011, both the world's total production of PV modules and the combined world capability for production of PV modules grew by an average of 78%/year. From 2011 to 2013, however, their respective annual growth rates fell to 4%/year and 8%/year. In addition, the difference between global PV module manufacturing capability and production has grown in recent years, leading to lower utilization rates of manufacturing facilities. In 2013, global PV module production was 39.9 gigawatts (GW), and global PV module manufacturing capability was 60.5 GW/year. The difference between production and capability in 2013 was 20.6 GW/year, up from 15.4 GW/year in 2011 (Figure 5-5).

In reaction to the slow growth of module production and the excess capacity for PV manufacturing, PV manufacturing companies have been downsizing and consolidating. For example, Germany reported to the International Energy Agency (IEA) that a total of 40 PV companies were operating in that country at the end of 2013, with approximately 11,000 employees, down from 62 companies with more than 32,000 employees at the end of 2008.[171] Similar trends were reported by China.

China continues to be the largest producer of PV modules, accounting for more than 60% of annual global production in recent years—23 GW in 2012 and 26 GW in 2013 (Figure 5-6). However, China is the sixth-largest market for PV, behind Germany, Italy,

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Table 5-2. OECD and non-OECD net renewable electricity generation by energy source, 2010–40 (billion kilowatthours)

Energy source by region	2012	2020	2025	2030	2035	2040	Average annual percent change, 2012–40
OECD	**2,168**	**2,976**	**3,210**	**3,412**	**3,687**	**3,987**	**2.2**
Hydroelectricity	1,375	1,482	1,532	1,558	1,592	1,696	0.8
Wind	379	806	910	1,017	1,198	1,310	4.5
Geothermal	42	74	90	107	121	135	4.2
Solar	92	228	247	270	291	324	4.6
Biomass, waste, tide/wave/ocean	281	385	432	460	485	522	2.2
OECD with CPP	**2,168**	**3,038**	**3,582**	**3,810**	**4,099**	**4,432**	**2.6**
Hydroelectricity	1,375	1,485	1,536	1,562	1,596	1,699	0.8
Wind	379	846	1,220	1,334	1,493	1,592	5.3
Geothermal	42	74	91	108	121	134	4.2
Solar	92	237	300	347	405	489	6.1
Biomass, waste, tide/wave/ocean	**281**	**395**	**435**	**458**	**483**	**518**	**2.2**
Non-OECD	**2,559**	**3,898**	**4,683**	**5,270**	**5,957**	**6,641**	**3.5**
Hydroelectricity	2,270	2,812	3,095	3,258	3,554	3,875	1.9
Wind	142	506	693	845	995	1,143	7.7
Geothermal	26	65	118	202	230	261	8.6
Solar	11	219	352	452	556	638	15.7
Biomass, waste, tide/wave/ocean	110	296	425	513	622	725	7.0
Total World	**4,727**	**6,874**	**7,893**	**8,682**	**9,644**	**10,628**	**2.9**
Hydroelectricity	3,645	4,294	4,626	4,816	5,146	5,571	1.5
Wind	520	1,312	1,603	1,863	2,192	2,452	5.7
Geothermal	68	139	208	309	352	395	6.5
Solar	103	448	599	722	847	962	8.3
Biomass, waste, tide/wave/ocean	391	681	857	973	1,107	1,247	4.2
Total World with CPP	**4,727**	**6,936**	**8,265**	**9,080**	**10,056**	**11,073**	**3.1**
Hydroelectricity	3,645	4,297	4,631	4,820	5,150	5,574	1.5
Wind	520	1,352	1,914	2,180	2,488	2,735	6.1
Geothermal	68	140	209	310	352	395	6.5
Solar	103	456	652	799	961	1,127	8.9
Biomass, waste, tide/wave/ocean	391	691	860	971	1,105	1,242	4.2

[171] International Energy Agency, Photovoltaic Power Systems Programme, "National Survey Reports," http://www.iea-pvps.org.

Japan, Spain, and France. China installed 0.2 GW of solar PV capacity in 2012, bringing its total installed PV capacity to 3.3 GW at the end of the year.

At the end of 2012, global installed solar PV capacity totaled 90 GW. More than 30 countries have established national solar generation capacity targets for 2020, and many other countries have set targets for years before or after 2020. The combined national targets for 2020 total more than 350 GW. Total installed solar PV capacity in the top six countries represented 76% of the world total in 2012 and 61% of the global target total for 2020. At current PV manufacturing capability of 60 GW/year, there is sufficient capability to supply an additional 400 GW of new capacity between 2013 and 2020, well above the aggregated national targets.

It is important to note that national targets do not necessarily correspond with projections of future solar PV market capacity. In the IEO2016 projections, all stated objectives for installation of renewable electricity capacity, including solar PV are not necessarily achieved. Also, most countries continually adjust their targets. For example, India in mid-2015 increased its PV capacity target for 2022 from 20 GW to 100 GW.[172]

Figure 5-5. World solar photovoltaic manufacturing production and capability, 2006–13 (gigawatts)

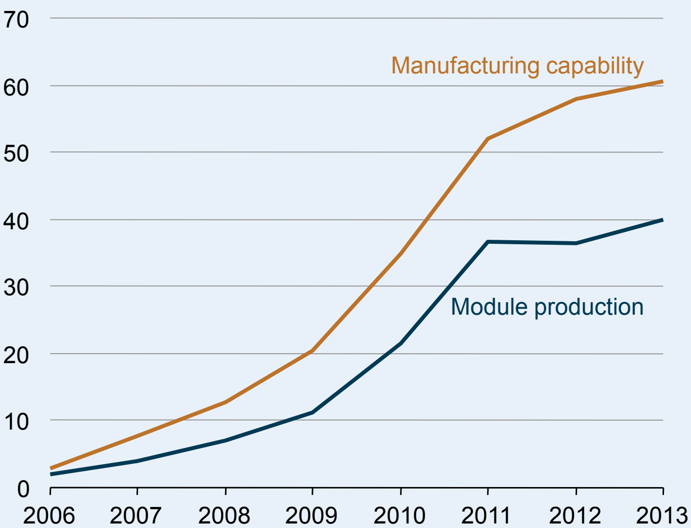
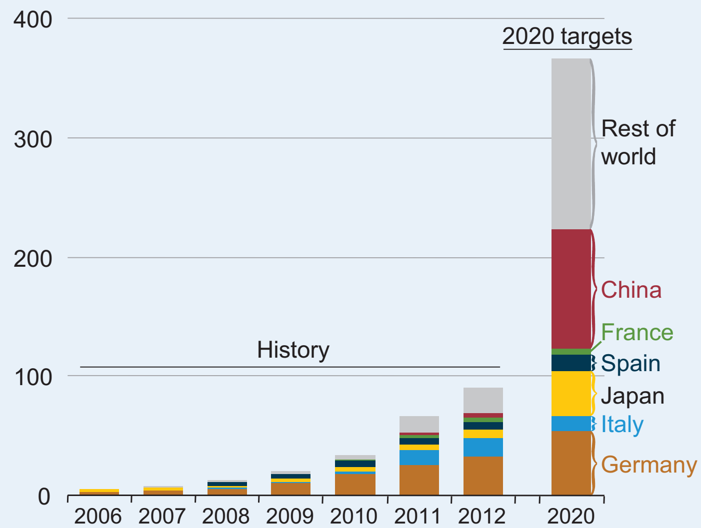


Figure 5-6. World installed solar photovoltaic capacity by country, 2006–12, and projected total installed capacity in 2020 (gigawatts)



Plans for hydroelectric generation capacity additions in Southeast Asia

The development of hydroelectric power in China—including the world's biggest hydropower plant at Three Gorges Dam—is substantially larger than planned expansions of hydroelectric power capacity in other countries of Southeast Asia.[173] The smaller countries in the region have announced plans to construct a combined total of 78 gigawatts (GW) of new hydroelectric generating capacity by the end of 2020. If those projects are completed, total hydropower capacity in the smaller countries will triple their combined 2012 capacity of 39 GW (Figure 5-7).

Many of the countries in Southeast Asia have access to the immense hydroelectric potential of the lower Mekong River, which flows through or borders China, Myanmar, Laos, Thailand, Cambodia, and Vietnam. Hydroelectric power potential in the Greater Mekong Region (which includes Mekong tributaries) is estimated to be between 175 GW and 250 GW.174 China already has constructed 6 major dams along the upper portion of the Mekong, and as of 2010 another 71 Mekong hydroelectric dams were proposed for completion in other Southeast Asia countries by 2030.175 Vietnam, Indonesia, Bhutan, and Laos already have announced plans for significant additions to hydroelectric capacity in the Mekong region, as well as projects centered on other hydroelectric resources.

(continued on page 87)

[172]T. Kenning, "Government of India officially approves 100GW solar target" (June 18, 2015), http://www.pv-tech.org/news/government_of_india_officially_approves_100gw_solar_target.

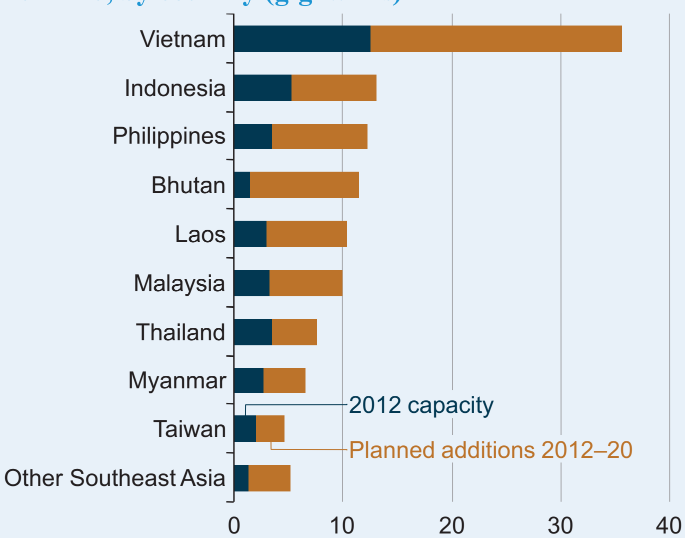
[173]U.S. Energy Information Administration, International Energy Statistics database (Washington, DC: October 2015), http://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm?tid=2&pid=2&aid=7&cid=r7,&syid=2008&eyid=2012&unit=MK.

[174]Mekong River Commission, *State of the Basin Report: 2010* (Vientiane, Laos: October 2010), http://www.mrcmekong.org/assets/Publications/basin-reports/MRC-SOB-report-2010full-report.pdf.

[175]International Centre for Environment Management, *Strategic Environmental Assessment of Hydropower on the Mekong Mainstream: Summary of the Final Report* (Melbourne, Australia: October 2010), http://www.mrcmekong.org/assets/Publications/Consultations/SEA-Hydropower/SEA-FR-summary-13oct.pdf.

- Vietnam has the most ambitious hydroelectric development plan in Southeast Asia, with plans to increase total hydroelectric capacity to 21.6 GW in 2020 and to 27.8 GW by 2030.[176] One of the largest planned projects is Trung Son, to be located on the Ma River in northern Vietnam (which is not a Mekong tributary), with an expected capacity of 360 megawatts (MW).[177]
- Indonesia's goal is to develop 3 GW of new hydroelectric generating capacity,[178] including the 1,040-MW Upper Cisokan pumped storage power facility, expected to be in service by the end of 2018, which would be one of the largest hydroelectric projects outside China.[179]
- Bhutan, a relatively small, mountainous country surrounded by India and China, plans to build 10 GW of hydroelectric generating capacity, with much of the electricity to be exported to India, which is funding the projects. Many of Bhutan's rivers feature high vertical drops over short distances, which are ideal for hydroelectric generation. Three of the proposed facilities, with a combined capacity of 2,940 MW, are currently under construction.
- Laos, with existing hydroelectric generating capacity of about 2.5 GW, plans to add more than 6.5 GW by 2020, including 17 projects—with a combined total capacity of more than 4.5 GW—that are in planning stages. More than one-fourth of the planned capacity in Laos is represented by the 1,285-MW Xayaburi hydroelectric power plant, which is the first of 11 planned hydroelectric generating plants along the lower Mekong River. Laos, like Bhutan, expects to be a major electricity exporter.[180]

Figure 5-7. Hydroelectric generating capacity in Southeast Asia, 2012, and planned additions, 2012–20, by country (gigawatts)



Note: Other Southeast Asia includes Cambodia, Singapore, Bangladesh, Papua New Guinea, and Nepal.

Despite the strong development and electrification potential of the planned Mekong River projects, there are major concerns about the environmental impacts of damming the Mekong and other rivers in Southeast Asia. An independent Strategic Environmental Assessment prepared for the Mekong River Commission[181] recommended a 10-year delay in the current schedules for hydroelectric projects in the region to address environmental concerns.

Hydropower development potential is much lower in the OECD member countries than in the non-OECD countries, because most of the OECD region's economically feasible hydroelectric resources already have been developed. Instead, the greatest potential for growth in renewable energy production in the OECD countries is from nonhydroelectric sources, especially wind, solar, and wood pellets *(see "World markets for wood pellets," below)*. Many OECD countries, and particularly those in Europe, have government policies that encourage the construction of wind and other nonhydroelectric renewable electricity generation facilities.[182]

World markets for wood pellets

Global production of wood pellets has increased significantly over the past five years, and demand in the European Union (EU) has led to international trade in this renewable energy source. In 2013, the EU accounted for 85% of the world's total consumption of wood pellets for energy production.[183] Wood pellets can be used for heating homes and businesses and as a fuel for small-scale industrial boilers. In the United Kingdom, Belgium, and the Netherlands, they are used predominantly for utility-scale electricity generation.

(continued on page 88)

[176] T. Minh, "PM approves adjustments to electricity plan," *Vietnam Economic Times* (March 19, 2016), http://vneconomictimes.com/article/vietnam-today/pm-approves-adjustments-to-electricity-plan.

[177] The World Bank, "Vietnam: Trung Son Hydropower Project: Map 2: Area of Project Activities" (December 2010), http://www.worldbank.org/content/dam/Worldbank/document/vn-trung-son-map.pdf.

[178] PWC Indonesia, *Power in Indonesia: Investment and Taxation Guide*, Second Edition (April 2013), http://www.pwc.com/id/en/publications/assets/electricity-guide-2013.pdf.

[179] P. Johansen, "Indonesia - Upper Cisokan Pumped Storage Hydro-Electrical Power (1040 MW) Project : P112158 - Implementation Status Results Report: Sequence 06 (English)" (World Bank Group: December 15, 2014), http://documents.worldbank.org/curated/en/2014/12/23026604/indonesia-upper-cisokan-pumped-storage-hydro-electrical-power-1040-mw-project-p112158-implementation-status-results-report-sequence-06.

[180] M. Harris, "Gate installation begins at Laos' 1,285-MW Xayaburi hydropower plant," *Hydro Review* (Luang Prabang, Laos: September 2, 2014), http://www.hydroworld.com/articles/2014/09/gate-installation-begins-at-laos-1-285-mw-xayaburi-hydropower-plant.html.

[181] International Centre for Environment Management, *Strategic Environmental Assessment of Hydropower on the Mekong Mainstream: Final Report* (Melbourne, Australia: October 2010), http://www.mrcmekong.org/assets/Publications/Consultations/SEA-Hydropower/SEA-Main-Final-Report.pdf.

[182] The IEO2015 projections include only marketed renewables as renewable energy sources. Nonmarketed traditional biomass from plant and animal resources is not included, because comprehensive data on its use are not available.

[183] A. Goetzl, *Developments in the Global Trade of Wood Pellets*, U.S. International Trade Commission, Office of Industries Working Paper No. ID-039 (Washington, DC: January 2015), http://www.usitc.gov/publications/332/wood_pellets_id-039_final.pdf.

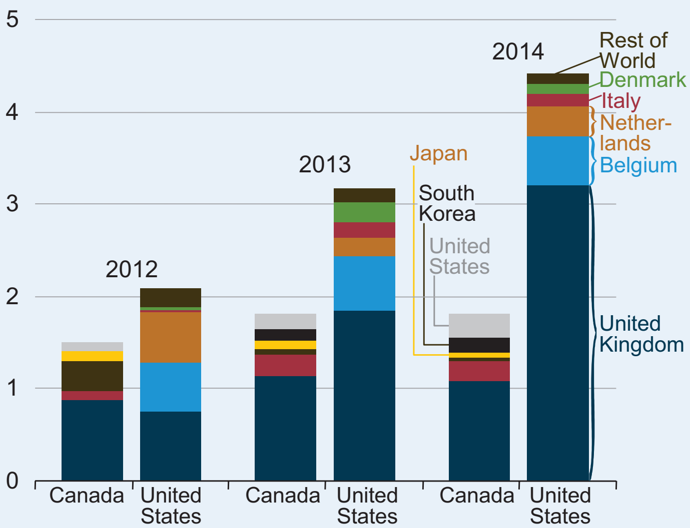
The increase in consumption of wood pellets in Europe is primarily a result of the European Commission's 2020 climate and energy plan, which calls for a reduction in greenhouse gas emissions and an increase in renewable energy as a percentage of total energy consumption,[184] with individual member states assigned national renewable energy targets. Until recently, the United Kingdom had relied on wood pellets in cofiring or dedicated biomass power plants as part of its compliance plan.[185] Approximately 45% of Europe's demand for wood pellets is met by trade within the EU, and the remainder is met primarily by imports from the United States, Canada, and Russia.

The United States currently is the world's largest exporter of wood pellets, having surpassed Canada in 2012. Total U.S. exports of wood pellets increased by nearly 40%, from 3.2 million short tons in 2013 to 4.4 million short tons in 2014 (Figure 5-8). According to the U.S. International Trade Commission and Statistics Canada, wood pellet exports from the United States and Canada in 2014 accounted for more than $500 million and $220 million in trade, respectively.[186] In 2014, almost three-quarters of all U.S. wood pellet exports were delivered to the United Kingdom, mainly for the purpose of generating electricity. The United Kingdom's renewable energy plan has resulted in plant operators of large coal-fired power plants either retrofitting existing units to cofire with wood pellets or converting them to dedicated biomass plants.[187]

Data from the United Kingdom (UK) Department of Energy and Climate Change indicate that electricity generation from plant-based biomass (which includes wood pellets) increased by 47%, from 8,933 gigawatthours (GWh) in 2013 to 13,138 GWh in 2014, led by the conversion of the Drax power plant in north-central England from coal to biomass.[188] The Drax plant, located east of Leeds, England, has six units that together are rated at nearly 4 gigawatts (GW) of electricity generation capacity. Data released by the Drax Group indicate that the first of six units was converted to dedicated biomass in 2013, and biomass provided 1.8 million short tons of fuel supply in that year.[189] A second unit was converted in 2014, and the amount of biomass supplied to the plant increased by more than 150%, providing 4.5 million short tons of fuel.

In 2014, wood pellets supplied to the Drax power plant alone accounted for more than 80% of the wood pellets exported to the United Kingdom from the United States and 90% of the wood pellets sent from Canada. Almost 60% of all U.S. wood pellet exports and approximately 54% of all Canadian wood pellet exports in 2014 went to the Drax plant. The United States and Canada are the largest suppliers of pellets to the United Kingdom, providing 61% and 19% of its total supply, respectively, followed by the Baltic countries (10%) and Portugal (9%).

Figure 5-8. Top five destinations for wood pellets exported from Canada and the United States, 2012–14 (million short tons)



In July 2015, the UK Department of Energy and Climate Change announced that it was cutting subsidies to biomass by removing the grandfather clause in the Renewables Obligation (RO) for new dedicated biomass and cofiring projects. The two converted biomass units at the Drax plant are exempt from the subsidy cut, as the third unit will be when it is built.[190]

Demand for wood pellets also is increasing in South Korea and Japan, primarily for use with coal in cofiring applications. After the earthquake and tsunami in Japan in 2011 and the resulting closures of several nuclear plants, Japan has tried to close the gap in energy supply by increasing renewable energy generation. In South Korea, the introduction of a renewable portfolio standard in 2012 increased interest in the use of biomass and wood pellets for energy generation. Imports to the two countries come predominantly from Canada, Southeast Asia, and the United States.[191] According to Bloomberg New Energy Finance, South Korea's demand for wood pellets in 2014 was estimated at 2.2 million short tons, equal to approximately 40% of the United Kingdom's total.[192]

[184]European Commission, "2020 climate & energy package" (updated October 6, 2015), http://ec.europa.eu/clima/policies/strategies/2020/faq_en.htm.
[185]Cofiring is the simultaneous combustion of two different fuels—usually coal and biomass. Dedicated biomass plants run completely on biomass.
[186]A. Goetzl, *Developments in the Global Trade of Wood Pellets*, http://www.usitc.gov/publications/332/wood_pellets_id-039_final.pdf.
[187]United Kingdom, Department of Energy & Climate Change, Environment Agency, "Policy paper: 2010 to 2015 government policy: low carbon technologies" (May 8, 2015), https://www.gov.uk/government/publications/2010-to-2015-government-policy-low-carbon-technologies/2010-to-2015-government-policy-low-carbon-technologies.
[188]United Kingdom, Department of Energy & Climate Change, Statistics - national statistics, Energy Trends section 6: renewables (October 8, 2015) https://www.gov.uk/government/statistics/energy-trends-section-6-renewables.
[189]Drax Group plc, "Biomass Supply" (February 2015), http://www.drax.com/media/56583/biomass-supply-report-2014.pdf.
[190]K. Fletcher, "Drax discusses recent regulation changes in half-year results," *Biomass Magazine* (July 28, 2015), http://biomassmagazine.com/articles/12237/drax-discusses-recent-regulation-changes-in-half-year-results.
[191]A. Goetzl, *Developments in the Global Trade of Wood Pellets,* U.S. International Trade Commission, Office of Industries Working Paper No. ID-039 (Washington, DC: January 2015), http://www.usitc.gov/publications/332/wood_pellets_id-039_final.pdf.
[192]Bloomberg New Energy Finance, www.bnef.com (subscription site).

Nuclear power

Worldwide electricity generation from nuclear power increases from 2.3 trillion kWh in 2012 to 4.5 trillion kWh in 2040 in the IEO2016 Reference case, with energy security concerns and limits on greenhouse gas emissions encouraging the development of new nuclear capacity. In addition, world average capacity utilization rates for nuclear power plants have continued to rise over time, from 68% in 1980 to 80% in 2012. In some regions, utilization rates could continue rising in the future. Factors underlying the nuclear power projections in the IEO2016 Reference case include the consequences of the March 2011 disaster at Fukushima Daiichi, Japan; planned retirements of nuclear power plants in OECD Europe under current policies; and continued strong growth of nuclear power capacity in non-OECD Asia *(see "Variability in electricity generation capacity factors by region and fuel," below).*

Variability in electricity generation capacity factors by region and fuel

Across the IEO regions, the mix of fuels and technologies used for electricity generation is limited, but the patterns of generator use—measured by annual capacity factors, or the ratio of generation to capacity—vary significantly. Analysis of generating plant utilization from 2008 through 2012 shows wide variability among fuel types and among world regions.

The variations in annual capacity factors can be attributed to a wide range of factors:

- Differences in daily load patterns, which reflect the mix of demand from buildings and industry, among other factors
- Differences in operating costs, which are driven mainly by fuel costs
- Planned outages of units to meet regulatory and maintenance requirements, as well as unplanned outages
- Differences in the efficiencies of generating technologies
- Constraints resulting from resource availability, commonly associated with generators that use renewable resources.

Annual capacity factors also can be affected by partial-year generation effects if the unit was installed within the past year. By convention, the numerator of the capacity factor is the actual generation from the unit, and the denominator is what that generator could have provided, assuming continuous operation for a full year. Projects commissioned in the second half of the year will have only a few months of generation to report, resulting in capacity factors lower than expected for a full year of operation. The data presented here reflect five-year averages ending in 2012,[193] the most recent year for which both generation and capacity data are available for all of the geographic areas discussed (Figure 5-9).

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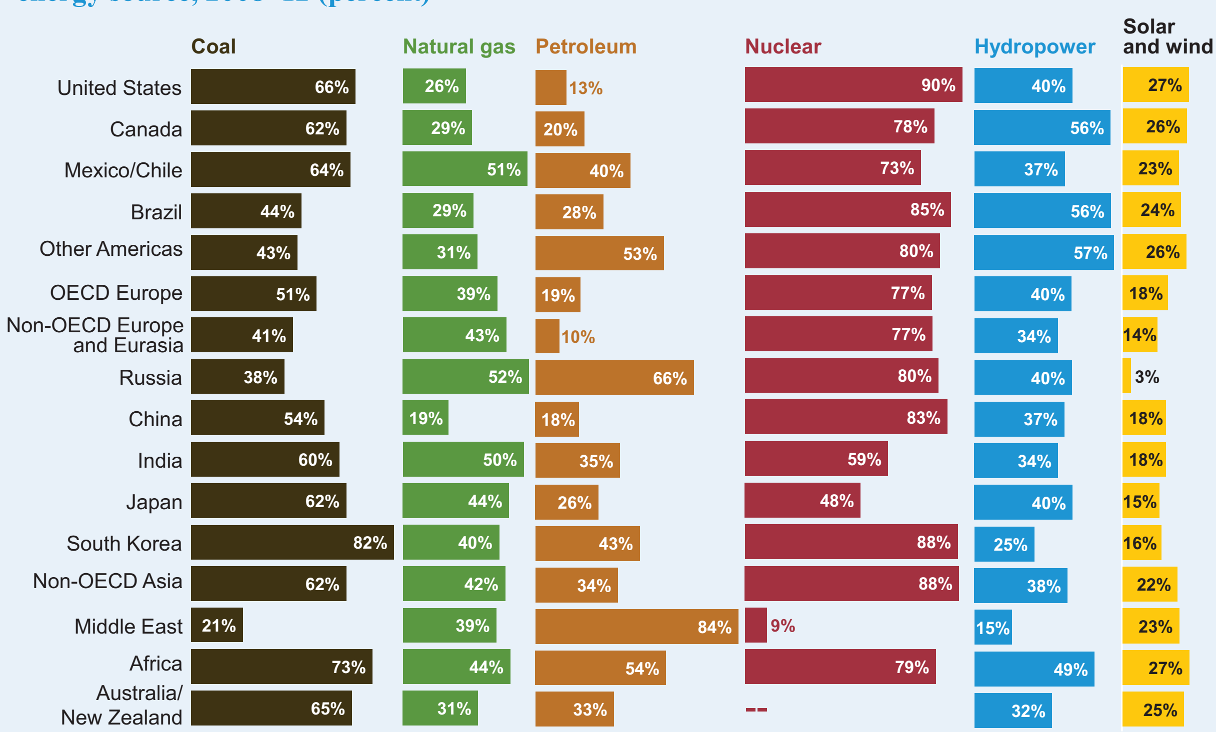
Figure 5-9. Average annual capacity factors for electricity generators by IEO region and energy source, 2008–12 (percent)



Note: Solar and wind capacity factors for Russia and the Other Americas region include only wind capacity. Australia/New Zealand has no installed nuclear capacity.

[193]Capacity factors for the five-year period are averages, weighted for generators' annual capacities. For regions with capacity factors missing for some years, only the available capacity factors are used to calculate the five-year weighted average.

Renewable electricity generating plants depend on the availability of renewable resources, such as solar, wind, and water. Because the use of renewable technologies, such as wind and solar, is growing rapidly in many regions—often starting from relatively small installed baselines—reported capacity factors are particularly affected by partial-year generation effects. Solar capacity factors are highest in India and in parts of Africa, where the availability of solar resources is high. Similarly, wind capacity factors are highest in Australia and New Zealand, and hydroelectric capacity factors are highest in Canada and South America.

In the United States, the five-year average solar capacity factor is 15%. In comparison, solar capacity factors in other countries and regions are considerably lower: solar generators in Canada have a five-year average capacity factor of 6%; non-OECD Europe and Eurasia 5%; and the Middle East 8%. Rapid expansion of solar capacity from 2008 through 2012 resulted in partial-year generation effects, contributing to low five-year average utilization. Another explanation for low solar capacity factors in some regions is the common convention of reporting solar photovoltaic (PV) capacity in terms of the direct current (DC) nameplate rating of PV panels, rather than in terms of the alternating current (AC) rating of the grid-tied inverter for the system. Because generation typically is measured and reported in AC terms, and solar PV systems often are designed with lower AC ratings than DC ratings, their apparent capacity factors are lower than they would be if the capacity were reported in DC terms.[194]

In many regions of the world, including the United States, the average capacity factor of wind generating facilities from 2008 through 2012 was approximately 30%; however, the average capacity factor for wind facilities in China during the same period was 18%, primarily because of partial-year generation effects caused by rapid capacity expansion. The 3% capacity factor for wind facilities in Russia is particularly low. Most of Russia's small-scale wind production facilities are located in agricultural areas with low population densities, and as a result, there are lags in connecting them to the grid.[195]

Capacity factors for nuclear power plants are the least variable. Nuclear plants typically operate throughout the year as baseload generation sources in most countries. However, operational or regulatory requirements can interrupt their production, as in the case of Japan's 2011 earthquake, which resulted in a low five-year average capacity factor for all nuclear generators in Japan because of the prolonged shutdown of the country's reactors that followed.[196] In the United States, the baseline average annual capacity factor for nuclear power generating plants from 2008 through 2012 was 90%. In other countries and regions, nuclear capacity factors average 73%, as a result of different operating policies and regulatory requirements. The differences in regulatory and operational requirements between OECD Europe and the United States, including nuclear refueling schedules, contributed to the 77% baseline nuclear plant capacity factor for OECD Europe from 2008 through 2012, which was 13% lower than the U.S. average.

Capacity factors for fossil-fired generators also can vary widely within a single country or region. Coal-fired generation has been the most economic form of fossil fuel generation in many regions, but growing environmental concerns associated with coal-fired generation, as well as competition from natural gas-fired and renewable generation, has recently led to lower capacity factors for coal-fired power plants in some countries. For example, South Korea's fleet of coal-fired power plants had an average capacity factor of 82% from 2008 through 2012, while the average for natural gas-fired plants and petroleum-fired plants was about 40%. Coal-fired units had significantly higher capacity factors because of significant improvements in efficiency (in 2010, 70% of South Korea's total coal-fired generation came from highly efficient supercritical units[197]). Also, with the price of coal in South Korea much lower than the price of imported liquefied natural gas, producers generated more electricity from the country's fleet of coal-fired power plants.[198]

In contrast to South Korea, coal-fired power plants in the United States recorded a 66% capacity factor from 2008 through 2012. The United States reported strong growth in both capacity and generation for power plants using natural gas and renewables, in part as the result of falling natural gas prices and new policies that promoted the adoption of renewable energy. In addition, the U.S. coal-fired generator fleet comprised primarily low-efficiency, aging subcritical units. In 2012, about half of all U.S. coal power plants were at least 40 years old. In addition, the installation and operation of pollution-control equipment required by a range of regulatory policies on emissions led to rapid increases in operating costs that discouraged the use of coal for power generation, even as average coal prices remained consistently low from 2008 through 2012.

A substantial share of China's total generating capacity consists of subcritical coal-fired units, and China reported an average capacity factor of 51% for its coal-fired fleet from 2008 through 2012, even as it was aggressively upgrading its coal-fired fleet with

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[194]For example, a typical solar PV plant might have a DC rating of 10 megawatts (MW) and an AC rating of 8 MW. If the plant produced 14,016 MWh of AC generation per year, its AC-rated capacity factor (based on AC generation) would be 20%, but its apparent DC-rated capacity factor, based on the DC capacity rating and the AC generation, would be only 16%.

[195]A.A.M. Singh (editor), *Renewable Energy—Renewables: The Energy for the 21st Century,* Part IV (Oxford, UK: Elsevier Science Ltd., 2000), p. 2560, https://books.google.com/books/about/Renewable_Energy.html?id=8NEeAQAAIAAJ.

[196]U.S. Energy Information Administration, "Japan restarts first nuclear reactor under new safety rules," *Today in Energy* (August 12, 2015), http://www.eia.gov/todayinenergy/detail.cfm?id=22472.

[197]Under ideal conditions, an ultra-supercritical turbine cycle system can convert steam into rotational energy at 54% or higher efficiency, supercritical turbine cycles can achieve 50% efficiency, and subcritical turbine cycles can achieve 46% efficiency.

[198]K. Burnard and S. Bhattacharya, *Power Generation from Coal: Ongoing Developments and Outlook* (Paris, France: International Energy Agency, October 2011), https://www.iea.org/publications/freepublications/publication/Power_Generation_from_Coal2011.pdf.

supercritical and ultra-supercritical units. The relatively low capacity factor for coal-fired power plants can be explained by the use of coal-fired units to satisfy peak demand requirements in China, a rapid buildup of new coal-fired capacity, and a large increase in hydroelectric generating capacity during that period.

OECD Europe's relatively low 54% capacity factor for coal-fired generators from 2008 through 2012 can be explained by the combination of lower electricity demand and growth in renewable capacity (65% annual growth in solar capacity and 13% annual growth in wind capacity over the four-year period), driven by Europe's regulatory policies related to power plant emissions, as well as increased penetration of natural gas as a fuel for electricity generation (4% annual growth).

Because natural gas and petroleum prices are typically higher than coal prices in most regions, plants using natural gas or petroleum usually operate during periods of peak and intermediate demand for electricity. Both Mexico and Russia, with high levels of natural gas production, demonstrated relatively high capacity factors for natural gas-fired generation from 2008 through 2012. Similarly, the Middle East, with abundant domestic petroleum resources, maintained a high capacity factor (84%) for its petroleum-fired generating fleet.

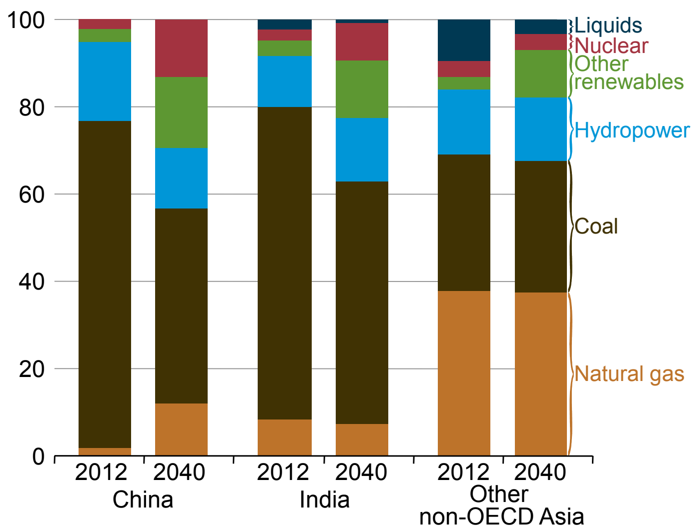
Despite significant public opposition to nuclear power in Japan,[199] two nuclear reactors at Sendai[200] were restarted in 2015 under new safety standards put in place after the 2011 Fukushima disaster. In Europe, Germany aims to move from fossil fuel-based electricity generation to a largely carbon-free energy sector while also phasing out nuclear energy by 2022.[201] In 2014, the French Parliament adopted a law to reduce the nuclear share of its total electricity generation from more than 75% in 2014 to 50% by 2025.[202] Among the developed OECD countries, only South Korea has a sizable increase in nuclear capacity (15 GW) through 2040 in the IEO2016 Reference case. However, reductions of nuclear power capacity in Canada, OECD Europe, and Japan more than offset South Korea's increase. As a result, total OECD nuclear power capacity declines by 6 GW from 2012 to 2040.

Almost all the nuclear capacity additions in the IEO2016 Reference case occur in non-OECD countries. In contrast to developments in OECD Europe, nuclear electricity generation grows significantly in Asia, with the strongest growth projected for China and India. In addition, sizeable increases are projected for nuclear power capacity in the Middle East. Average annual growth rates for nuclear electricity generation from 2012 to 2040 in the Reference case include 9.6% in China, 7.9% in India, and 2.9% in the other non-OECD Asia economies. China has the largest projected increase in nuclear capacity, adding 139 GW from 2012 to 2040, followed by 36 GW in India and 8 GW in the remaining non-OECD Asian countries. In the Middle East, nuclear capacity increases from less than 1 GW in 2012 to 22 GW in 2030.

Regional electricity markets in non-OECD Asia

In non-OECD Asia, with some of the world's fastest-growing economies, electricity demand is expected to grow strongly as standards of living rise, and as demand for lighting, heating and cooling, and electric appliances increases. Non-OECD Asia remains the fastest-growing region in the world, with projected GDP growth of 4.7%/year through 2040. Many of the key non-OECD Asia economies (including Hong Kong, Indonesia, Singapore, and Taiwan) rely heavily on exports, both to China and to OECD nations. For these export-dependent Asian countries, slower economic growth in China and the OECD at large is likely to lower their own GDP growth in the near term.

Figure 5-10. Non-OECD Asia electricity generation fuel mix by region, 2012 and 2040 (percent of total)



In view of increasing pressure to reduce greenhouse gas emissions, the likely responses of the non-OECD Asia subregions are reflected in projections for coal-fired shares of total electricity generation. In particular, the most significant reduction in coal-fired generation among the non-OECD Asia regions in the IEO2016 Reference case is projected for China (Figure 5-10).

China

Despite some moderation in its projected economic growth, China remains one of the world's fastest-growing economies in the IEO2016 Reference case. As a result, its total net electricity

[199] A. Sheldrick and I. Kato, "Japan restarts reactor in test of Abe's nuclear policy," *Reuters* (August 11, 2015), http://www.reuters.com/article/us-japan-nuclear-restarts-idUSKCN0QF0YW20150811.

[200] U.S. Energy Information Administration, "Japan restarts first nuclear reactor under new safety rules," *Today in Energy* (August 12, 2015), http://www.eia.gov/todayinenergy/detail.cfm?id=22472.

[201] K. Appunn, "The history behind Germany's nuclear phase-out, " *Clean Energy Wire* (July 24, 2015), https://www.cleanenergywire.org/factsheets/history-behind-germanys-nuclear-phase-out.

[202] World Nuclear News, "French parliament approves energy transition" (October 13, 2014), http://www.world-nuclear-news.org/NP-French-parliament-approves-energy-transition-1310144.html.

generation nearly doubles from 4.8 trillion kWh in 2012 to 9.4 trillion kWh in 2040, at an average annual growth rate of 2.5%. The impact of China's continued rapid economic development on the environment has become a primary concern among environmental policymakers in China and also for the general public. In particular, China recently introduced a number of policies and proposals to address heightened concerns about air quality. In a joint statement in November 2014, both China and the United States committed to actions designed to ensure long-run reductions in emissions, with China targeting a reduction in CO2 emissions beginning by 2030.[203] China is moving to generate more electric power from nuclear power, renewables, and natural gas to address environmental concerns and to diversify its electricity generation fuel mix toward energy sources with lower or zero emissions of greenhouse gases.

In June 2015, China outlined the specific steps needed to achieve a decline in its CO2 emissions beginning in 2030. The government's INDC policy includes the following energy-related targets for China:

- Lower carbon intensity (CO2 per unit of GDP) by 60% to 65% compared with 2005 levels
- Increase the share of nonfossil fuels in the primary energy mix to approximately 20%.[204]

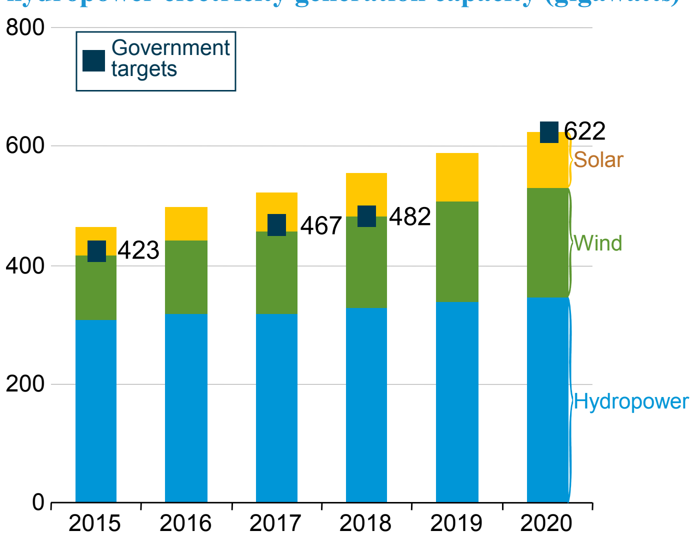
At the time of the announcement of its commitment to peak emissions in 2030, China's government officials estimated that to achieve that target it would be necessary to build 800–1,000 gigawatts of non-emitting generating capacity by 2030, thus offering a comparative benchmark for projections.[205]

In adapting assumptions regarding China's announced multisector policies to achieve emissions reductions in the electric power sector, IEO2016 combines the application of broad policy levers to alter the use of fossil generation in the projection with detailed analysis of renewable targets, including assessment of their timing and achievement up to 2030.

In recent years, the cost of renewable technologies has continued to decline, with the greatest cost reductions recorded for solar technologies. However, clean energy policy goals also play a major role in the adoption of renewable energy sources in China. Renewables policy targets include both the stated specific national-level goals formally included in various Five-Year Plans and an interpretation of the implications of general policy commitments to additions of renewable generating capacity (for example, capacity growth resulting from the preservation of renewables market share after the deadlines for achieving renewable targets have passed). The 12th Five-Year Plan (2011–15) includes a target to increase nonfossil energy sources (including hydropower, nuclear, and renewable energy) to 11.4% of total energy use (up from 8.3% in 2010). In addition, the plan sets a 15% overall target for the renewable share of total electricity generation in 2020.

China's renewable energy outlook in the IEO2016 Reference case reflects the policy effects of identified Chinese government targets for specific renewable fuel types from 2015 to 2020, the results for previous Five-Year Plans, and the economic outlook for growth in the electric power sector through the next decade. Projected renewable energy capacity additions are on track to achieve a combined 622 GW of total installed hydroelectric, wind, and solar generating capacity in 2020 (Figure 5-11). At that rate, renewables and nuclear power would fulfill their part in China's INDC to increase the share of non-fossil fuels in the primary energy mix to approximately 20% by 2030. Strong growth in both wind and solar installed generating capacity supports the projected growth in China's renewable energy use, with installed solar capacity increasing from 3 GW in 2012 to 184 GW in 2040 and wind energy capacity increasing from 61 GW in 2012 to 350 GW in 2040.

Figure 5-11. China renewable electricity generation capacity in the IEO2016 Reference case, 2015–20, and aggregate government targets for solar, wind, and hydropower electricity generation capacity (gigawatts)



In 2012, coal's share of China's total electricity generation was estimated at 75%. Assuming the phase-in of various government policies through 2030 in the IEO2016 Reference case, the coal share declines to an estimated 53% in 2030 and to 44% in 2040 (Figure 5-12). Overall, renewable electricity generation increases by an average of 3.8%/year and nearly triples, from 1,004 billion kWh in 2012 to 2,878 billion kWh in 2040. Solar is China's fastest-growing energy source in the IEO2016 Reference case, with annual growth averaging 15.4% through 2040.

Another rapidly growing energy source in China's electric power sector in the IEO2016 Reference case is nuclear power generation. Net electricity generation from the country's nuclear power plants grows by an average of 9.6%/year, from 93 billion kWh in 2012 to 1,212 billion kWh in 2040. In addition, although natural gas previously has not played a significant role

[203]"FACT SHEET: U.S.-China Joint Announcement on Climate Change and Clean Energy Cooperation," White House press release (November 11, 2014), https://www.whitehouse.gov/the-press-office/2014/11/11/fact-sheet-us-china-joint-announcement-climate-change-and-clean-energy-c.
[204]World Resources Institute, "CAIT Climate Data Explorer: China" (last updated July 1, 2015), http://cait.wri.org/indc/#/profile/China.
[205]"FACT SHEET: U.S.-China Joint Announcement on Climate Change and Clean Energy Cooperation," White House press release (November 11, 2014), https://www.whitehouse.gov/the-press-office/2014/11/11/fact-sheet-us-china-joint-announcement-climate-change-and-clean-energy-c.

in China's electric power sector, natural gas-fired generation grows at a comparable rate of 9.9%/year from 2012 to 2040 in the Reference case. As a result, the natural gas share of total electricity generation increases from 2% in 2012 to 12% in 2040. A major factor in the expanding role of natural gas in electricity generation is an increase in sources of natural gas supply, including contracts with Russia for large-scale construction of natural gas pipelines between the two countries, financed by China, with the first stage calling for a pipeline with the capacity to carry 1.3 trillion cubic feet per year.[206]

India

India's need for energy continues to increase as a result of its economic growth and modernization over the past several years. With nearly a quarter of its population having no access to electricity, a significant component of progress for the Indian economy lies in the prospects for electrification.[207] As a result, India has one of the fastest-growing electricity sectors in the world. Between 2005 and 2012, India's net electricity generation increased by an average 6.6%/year (Figure 5-13). In the IEO2016 Reference case, net electricity generation in India increases from 1,052 billion kWh in 2012 to 2,769 billion kWh in 2040; at 3.5%/year, this is the fastest growth of any IEO2016 region over the projection period.

With a large-scale domestic production potential, coal is India's primary source of energy for electricity generation. However, as electricity demand has risen sharply, a widening gap between coal demand and supply has emerged, with coal shortages contributing to blackouts in India. In response to rapid demand growth, India has increased capacity and upgraded efficiency of its transmission grid, which has helped to reduce electricity losses. However, most of the country's remaining transmission and distribution losses are the result of theft *(see "Electricity transmission and distribution system losses in India," below)*.

Electricity transmission and distribution system losses in India

India's state-owned utilities have a history of large losses of electricity from their transmission and distribution (T&D) systems, resulting from both technical inefficiencies and theft. For example, in fiscal year (FY) 2001 nearly one-third of all the electricity generated by the utilities did not reach the intended customers.[208] Since FY 2001, the government's efforts have cut the country's total T&D losses to about one-fifth of the electricity generated and delivered to the power grid.

India's T&D losses are among the highest in the world (Figure 5-14). High loss levels have contributed to electricity supply outages throughout the country—including, in 2012, the largest power outage in the world.[209] They also have led to financial bailouts of the country's utilities by the central government in FY 2001 and FY 2011.[210] In FY 2014, average annual electricity demand exceeded the amount of electricity India's electric utilities could supply by 3.6% (and by 4.7% during periods of peak demand).[211] India's

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Figure 5-12. China electricity generation by fuel source, 2012–40 (trillion kilowatthours)

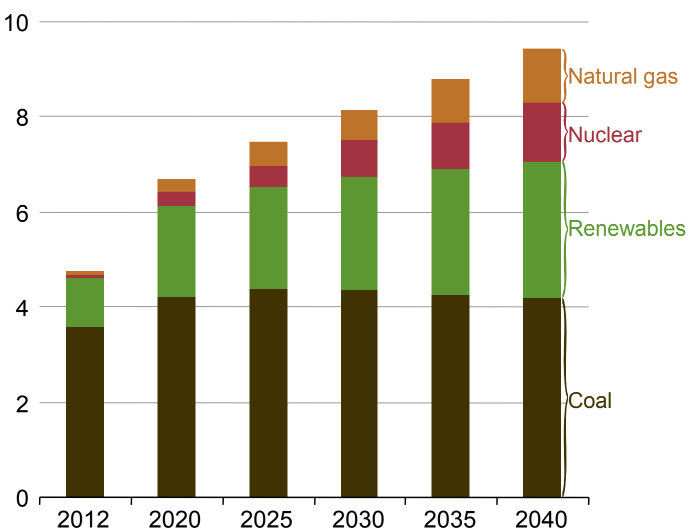
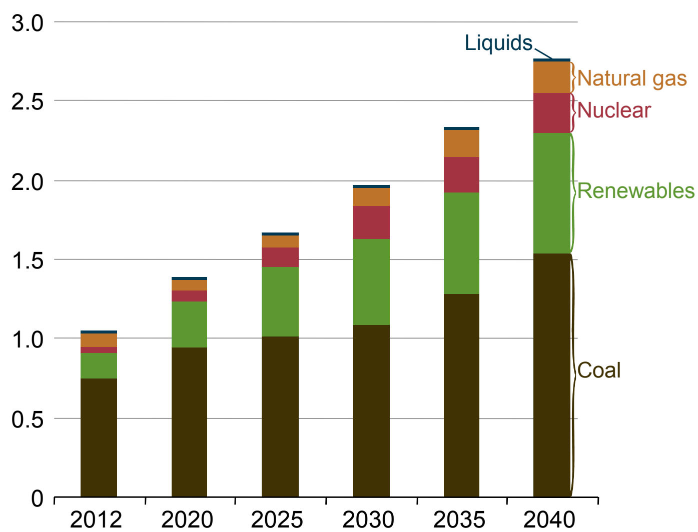


Figure 5-13. India electricity generation by fuel source, 2012–40 (trillion kilowatthours)



[206]C. Helman, "China-Russia Gas Deal Should Unleash A Euro-Fracking Revolution," *Forbes / Energy* (May 21, 2014), http://www.forbes.com/sites/christopherhelman/2014/05/21/china-russia-gas-deal-should-unleash-a-euro-fracking-revolution/.

[207]International Energy Agency, *World Energy Outlook 2014* (Paris, France: November 2014), p. 235.

[208]India's fiscal year runs from April 1 to March 31. FY 2001 ran from April 1, 2001, to March 31, 2002.

[209]H. Sarma and R. Russell, "Second day of India's electricity outage hits 620 million," *USA Today News* (July 31, 2012), http://usatoday30.usatoday.com/news/world/story/2012-07-31/india-power-outage/56600520/1; "Power Cuts in India," http://powercuts.in/reports.

[210]International Energy Agency, *Understanding Energy Challenges in India: Policies, Players and Issues* (Paris, France: 2012), http://www.iea.org/publications/freepublications/publication/India_study_FINAL_WEB.pdf.

[211]Government of India, Ministry of Power, Central Electricity Authority, *Load Generation Balance Report 2015-16* (New Delhi, India: May 2015), http://www.cea.nic.in/reports/yearly/lgbr_report.pdf.

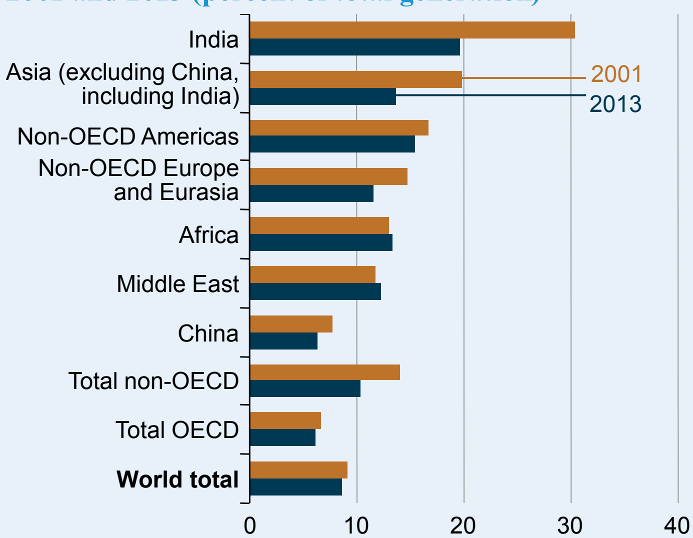
Central Electricity Authority, which is responsible for overall development of the power sector, expects a total electricity shortage of 2.1%, and a peak demand shortage of 2.6%, in FY 2015. Improving T&D losses by even a few percentage points would help lower the country's electricity shortages and help reduce the number of outages.

Technical losses are caused by the resistance of wires and equipment, when the electricity passing through them is converted to heat.[212] Normal T&D losses—generally between 6% and 8%[213]—can be reduced by upgrading transmission lines and power transformers and by improving electric power dispatch planning. T&D losses also can be reduced by improving operation and maintenance practices; upgrading power lines, transformers, insulation, voltage, and thermal monitoring systems; and modernizing metering systems.[214]

Recently, India has increased the capacity and upgraded the efficiency of its transmission grid. On February 25, 2009, the National Load Dispatch Center began supervising regional load dispatch centers, scheduling and dispatching electricity, and monitoring operations of the national grid.[215] In December 2013, the country's five regional grids were interconnected to operate at a synchronous frequency to transfer power more efficiently from generation sources to load centers.[216] In addition, Powergrid—the government agency in charge of national grid construction—has been developing high-capacity transmission corridors. Since 2002, the mileage and capacity of India's high-capacity/high-voltage direct-current lines, which reduce transmission losses over long distances in comparison with alternating-current lines, have more than doubled.[217]

Although improvement and expansion of the national grid have helped reduce electricity losses, most of India's T&D losses are the result of theft.[218] Thefts occur in two ways: when energy consumed is not accounted for (as a result of consumers rigging lines to bypass their electricity meters or directly tampering with their meters) and when customers avoid paying for some or all of the electricity they consume (often by bribing utility meter readers or billing agents).[219] Illegal power lines are above ground and easy to detect, but utility staff have been bribed or attacked while attempting to remove them.[220]

Figure 5-14. World electricity transmission and distribution losses by selected countries and regions, 2001 and 2013 (percent of total generation)



Utilities have not always received adequate reimbursement for providing state-mandated, subsidized electricity to the agricultural sector and to the poor, mainly because of poorly managed accounting systems. According to India's 2005 National Electricity Policy, the high levels of technical and commercial T&D losses and poor management of utilities have led to unsustainable financial operations.[221] In addition, subsidies paid to utilities by the central government to keep the utilities operating have risen to unsustainable levels. The latest reported data show that subsidies made up 12.8% percent of revenue from power sales in India's FY 2012.[222]

Collection efficiency issues also have contributed to T&D losses in India. Collection efficiency is a measure of the share of billed revenues that a utility is able to collect from its customers. For example, if the utility bills a customer for 100 MWh of electricity it has provided but is able to collect revenues accounting for only 80 MWh, the collection

(continued on page 95)

[212] ABB Inc., *Energy Efficiency in the Power Grid* (Norwalk, CT: 2007), http://www.nema.org/Products/Documents/TDEnergyEff.pdf.

[213] ABB Inc., *Energy Efficiency in the Power Grid* (Norwalk, CT: 2007), http://www.nema.org/Products/Documents/TDEnergyEff.pdf.

[214] R. Jackson et al., *Opportunities for Energy Efficiency Improvements in the U.S. Electricity Transmission and Distribution System,* ORNL/TM-2015/5 (Oak Ridge National Laboratory, Oak Ridge, TN: April 2015), p. 21, http://energy.gov/sites/prod/files/2015/04/f22/QER%20Analysis%20-%20Opportunities%20for%20Energy%20Efficiency%20Improvements%20in%20the%20US%20Electricity%20Transmission%20and%20Distribution%20System_0.pdf.

[215] Power System Operation Corporation Limited, "National Load Despatch Center" (undated), http://posoco.in/about-us/mission.

[216] Government of India, Ministry of Power, "Transmission," http://powermin.nic.in/Transmission-0.

[217] Government of India, Ministry of Power, Central Electricity Authority, *Executive Summary: Power Sector* (New Delhi, India: July 2015), http://www.cea.nic.in/new_website/reports/monthly/executivesummary/2015/exe_summary-07.pdf.

[218] R. Katakey and R. Kumar Singh, "India fights to keep the lights on," *Bloomberg Business* (June 5, 2014), http://www.bloomberg.com/bw/articles/2014-06-05/india-fights-electricity-theft-as-modi-pledges-energy-upgrade.

[219] V. Gupta, "A Comparative Analysis: Electricity Theft vis-a-vis Revenue Protection" (undated), https://www.upcl.org/wss/downloads/WhitePapers_pdfs/wp-7-elect-theft.pdf.

[220] R. Katakey and R. Kumar Singh, "India fights to keep the lights on," *Bloomberg Business* (June 5, 2014), http://www.bloomberg.com/bw/articles/2014-06-05/india-fights-electricity-theft-as-modi-pledges-energy-upgrade.

[221] Government of India, Ministry of Power, "National Electricity Policy" (February 12, 2005), http://powermin.nic.in/National-Electricity-Policy-0.

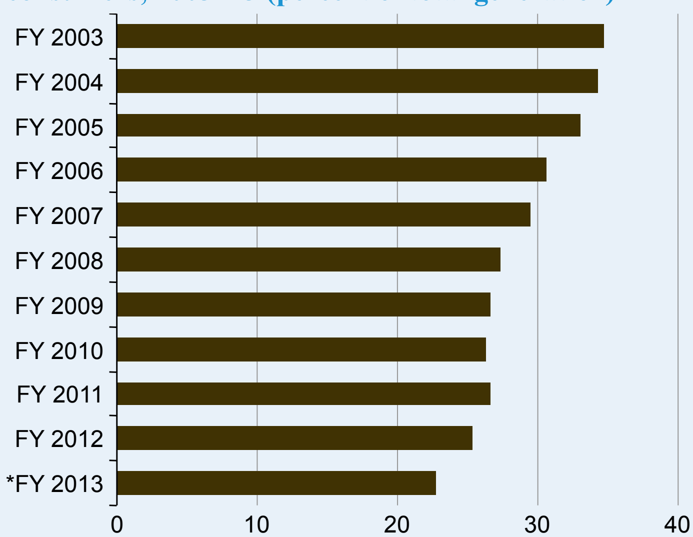
[222] Power Finance Corporation Ltd., *A Report on the Performance of State Power Utilities for the years 2010-11 to 2012-13* (May 2014), http://www.pfcindia.com/writereaddata/userfiles/file/Report%20for%20the%20years%202010-11%20to%202012-13%20Final.pdf.

efficiency is 80%. According to the Indian government's Power Finance Corporation, Ltd., collection efficiency among all utilities selling directly to consumers in FY 2013 was about 94%, suggesting that an average of 6% of the potential total utility revenues nationwide were instead financial losses.

Collection inefficiency has led the Indian government to institute plans to reduce aggregate technical and commercial (AT&C) T&D losses,[223] which represent the percentage difference between electricity generation available for sale (adjusted for transmission losses and trading) and electricity sold (adjusted by the collection efficiency factor). In 2001, the government launched its Accelerated Power Development and Reform Program (APDRP), with goals of strengthening the subtransmission and distribution network and reducing AT&C losses to 15% in five years. After failing to achieve that target, the Ministry of Power launched a Restructured APDRP (R-APDRP) in July 2008 specifically to reduce AT&C losses.[224] Loans and grants were used to establish baseline data, to set up information technology-based energy accounting and auditing systems and consumer service centers, and to strengthen and upgrade the subtransmission and distribution network. The goal was to reduce AT&C losses by 3%/year for utilities with AT&C losses greater than 30% and by 1.5%/year for all others, with supervisory control and data acquisition systems installed to monitor energy flows through power lines and substations.

After the 2011 government financial bailout of state distribution companies (Discoms), India's government approved a utility restructuring plan for state Discoms, providing financial rewards to companies that surpassed targets for lowering AT&C losses. In March 2012, a National Electricity Fund was established to promote investment in the power distribution sector.[225] The $1.3 billion fund provides interest subsidies on loans disbursed to both public and private Discoms to improve the distribution network for areas not already covered by rural electricity initiatives and for R-APDRP project areas. Eligibility for the loans is based on the undertaking of reform measures prescribed at the state level, and many of India's state governments have now adopted new regulations and technologies to improve tariff billing and collection practices.[226] The amount of the interest subsidy is linked to progress in achieving the reform measures.

Figure 5-15. Aggregated technical and commercial losses of Indian utilities that sell directly to consumers, 2003–13 (percent of total generation)



*Preliminary.

Since 2014, the Indian government has initiated more programs to improve grid operation and reduce losses. The Integrated Power Development Scheme (IPDS) was approved in November 2014, with a budget allocation of $3.8 billion from the national government.[227] The IPDS is intended to further strengthen subtransmission and distribution networks in urban areas by using information technology-based systems to meter distribution transformers, feeders, and urban consumption. In 2015, a new National Smart Grid Mission was established—with a budget allocation of almost $51 million—to work with Discoms and other financing agencies in planning smart grid projects to be implemented as funding is secured from public and private sources.[228]

AT&C losses in India have trended downward since FY 2003 (Figure 5-15). When the Ministry of Power released its latest evaluation of 40 power distribution entities in August 2015,[229] it announced that 21 power distribution companies had shown improvements in their AT&C loss levels from FY 2013 to FY 2014. Eight utilities were able to achieve reductions in AT&C losses greater than 20%, while 10 utilities showed increases greater than 10%.

[223] AT&C losses represent the difference between energy available for sale (MWh), adjusted for transmission losses and trading in energy, and energy realized (MWh). Energy realized is the energy billed, adjusted for trading in energy (MWh), factored by the collection efficiency. Collection efficiency is an index of efficiency in realization of billings for current and previous years, focusing on the year-to-year movement of receivables.

[224] Government of India, Ministry of Power, "Restructured Accelerated Power Development & Reforms Programme" (updated September 15, 2015), http://www.apdrp.gov.in/Forms/Know_More.

[225] Government of India, Ministry of Power, "Office Memorandum: Scheme for Restructuring of State Distribution Companies (Discoms)," No. 20/11/2012-APDRP (October 5, 2012), http://powermin.nic.in/upload/pdf/Financial_restructuring_of_State_Distribution_Companies_discoms_Oct2012.pdf.

[226] Government of India, Central Electricity Regulatory Commission, "State Electricity Regulatory Commissions – Links," http://www.cercind.gov.in/serc.html.

[227] Government of India, Ministry of Power, "Office Memorandum: Integrated Power Development Scheme" (IDPS), No. 26/1/2014-APDRP (December 3, 2014), http://powermin.nic.in/upload/pdf/Integrated_Power_Development_Scheme.pdf.

[228] Government of India, Ministry of Power, "Office Memorandum: National Smart Grid Mission" (NSGM), 20/13(2)/2009-APDRP (March 27, 2015), http://powermin.nic.in/upload/pdf/National_Smart_Grid_Mission_OM.pdf.

[229] Government of India, Ministry of Power, "State Distribution Utilities: Third Annual Integrated Rating" (August 2015), http://www.pfcindia.com/writereaddata/userfiles/file/Annual_IR/Third%20Anual%20IR%20of%20State%20Discoms_Final%20Website%20Soft%20Print.pdf.

While trying to accelerate economic growth, India also is attempting to address concerns about the environmental effects of rapid development. In October 2015, India issued an Intended Nationally Determined Contribution which set the following national goals to address climate change:

- Reduce CO2 emissions intensity by 33% to 35% from 2005 levels by 2030
- Nearly triple renewable energy capacity from 2012 levels by 2022
- Increase the share of zero-carbon electricity generating capacity to 40% of the total by 2030.[230]

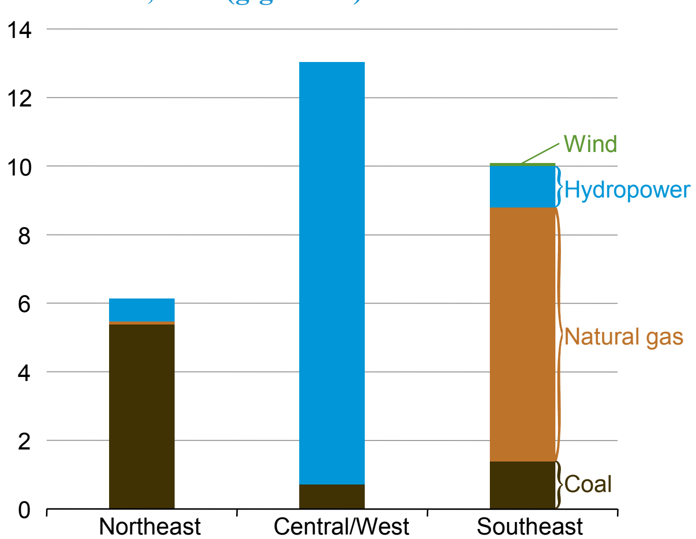
In 2012, 72% of India's electricity was generated at coal-fired power plants; that share falls to 55% in 2040 in the IEO2016 Reference case. According to the International Energy Agency, a shortage of coal and natural gas supplies for power generation is a pressing issue for India's power sector. Domestic natural gas production is also declining.[231] In the IEO2016 Reference case, natural gas production increases by an average of 1.3%/year from 2012 to 2040.

In an effort to diversify its electricity generation portfolio and limit emissions from fossil fuels, India's government is promoting renewable energy use. In total, renewables constituted 15% of India's electricity generation in 2012; in the IEO2016 Reference case, the renewables share increases to 28% in 2040. Net electricity generation from hydroelectric and other renewable sources increases from 160 billion kWh in 2012 to 764 billion kWh in 2040. India was the world's seventh-largest producer of hydroelectric power in 2012, with 125 billion kWh generated.[232] Hydroelectric generation increases in the Reference case to 405 billion kWh in 2040. In addition to renewables, India seeks to accommodate its swiftly growing power demand with increased nuclear generation. In the IEO2016 Reference case, India's nuclear power generation increases by 7.9%/year from 2012 to 2040, and the nuclear share of the country's total electricity generation rises to 9% in 2040.

Vietnam

Vietnam is expecting a significant transformation of its electric power generation mix, with plans to modernize its agrarian economy over the next two decades and become a more industrialized nation. Demand for electric power in Vietnam has increased over the past five years at annual growth rates of 10% to 12%. The Vietnamese government also is pursuing an enhanced level of energy security to support the country's economic transformation. Its National Strategy on Energy Development to 2020, with an outlook to 2050, lists "Policy to ensure national energy security" at the top of the energy policy agenda.[233]

Figure 5-16. Installed electricity generation capacity in Vietnam, 2014 (gigawatts)



Vietnam's interconnected electrical system relies heavily on hydroelectric power generation, and the 2005 Plan for Power Development (PDP) called for the installation of 17 GW to 18 GW of hydroelectric generating capacity between 2006 and 2015. However, as a result of environmental problems and concerns over social displacement, only about 4.1 GW has been developed so far.[234] To accommodate the expansion of its industrial sector, Vietnam is diversifying its installed generation capacity to include a larger share of coal- and natural gas-fired power plants[235] and is planning to build the first nuclear reactors in Southeast Asia and to complete the first offshore wind farm in Asia.[236]

The predominant energy sources for installed electricity generation capacity in Vietnam vary by geographic region—coal in the northeast, hydropower in the central and western areas, and natural gas in the southeast (Figure 5-16). Most of the country's electricity grid is concentrated around the capital (Hanoi) in the north and around Ho Chi Minh City (Saigon) in the south.

[230]World Resources Institute, "CAIT Climate Data Explorer: India," (last updated October 1, 2015), http://cait.wri.org/indc/#/profile/India.

[231]International Energy Agency, *Understanding Energy Challenges in India Policies: Players and Issues* (Paris, France: 2012), p. 43, https://www.iea.org/publications/freepublications/publication/India_study_FINAL_WEB.pdf.

[232]U.S. Energy Information Administration, "International Data and Analysis: India" (Washington, DC: June 26, 2014), http://www.eia.gov/beta/international/analysis.cfm?iso=IND.

[233]International Atomic Energy Agency, *Country Nuclear Power Profiles 2013 Edition,* "Vietnam" (April 2013), http://www-pub.iaea.org/MTCD/Publications/PDF/CNPP2013_CD/countryprofiles/Vietnam/Vietnam.htm.

[234]United Nations Environment Programme Dams and Development Project, "National Hydropower Plan for Vietnam," http://www.unep.org/dams/documents/ell.asp?story_id=15.

[235]International Atomic Energy Agency, *Country Nuclear Power Profiles 2013 Edition,* "Vietnam" (April 2013), http://www-pub.iaea.org/MTCD/Publications/PDF/CNPP2013_CD/countryprofiles/Vietnam/Vietnam.htm.

[236]power-technology.com, "Bac Lieu Offshore Wind Farm, Vietnam" (not dated, accessed August 16, 2015), http://www.power-technology.com/projects/bac-lieu-offshore-wind-farm/.

Ten main rivers and five main river basins supply Vietnam's existing hydropower system, with resources concentrated in the north, the central highlands, and the lower south central coast.[237] In 2014, Vietnam consumed 54.1 TWh of electricity generated from hydroelectric plants, a 1.3% increase from the 2013 total.[238] The country's slow growth in hydropower generation coincided with relatively weak 2.0% total world growth in hydropower production from 2013 to 2014.

The majority of Vietnam's coal-fired power plants are in the north. The country's proved reserves of anthracite and bituminous coal total 150 million metric tons,[239] concentrated primarily in Quang Ninh province, directly east of Hanoi. In 2014, Vietnam produced 41.2 million metric tons of coal, an increase of 0.5% from 2013. In comparison, coal consumption in 2014 was up by 20.6% from the 2013 level of 15.8 million metric tons, primarily as a result of industrial sector expansion.

Over the past decade, increases in foreign investment have supported wider exploration for natural gas in Vietnam, which has increased its proved natural gas reserves significantly. At the end of 2014, Vietnam held 21.8 trillion cubic feet (Tcf) of proved natural gas reserves after producing an annual total of 361 billion cubic feet (Bcf) of marketed natural gas, all of which was consumed domestically. Both production and consumption of natural gas in 2014 increased by 4.7% from the 2013 levels.[240] Although Vietnam currently is self-sufficient in natural gas, PetroVietnam predicts a potential supply gap, particularly in southeastern Vietnam, as consumption outpaces domestic production. Liquefied natural gas (LNG) regasification terminals are already in the planning stages.

The Mekong River Delta and southeastern Vietnam contain nearly all the country's installed natural gas-fired electricity generation capacity. Most of the natural gas reserves are located offshore, southwest from the tip of the Mekong Delta. In addition, ExxonMobil Vietnam recently announced a large discovery off the central coast and is partnering with PetroVietnam to determine potential locations for a thermal power and natural gas treatment complex in central Vietnam.[241]

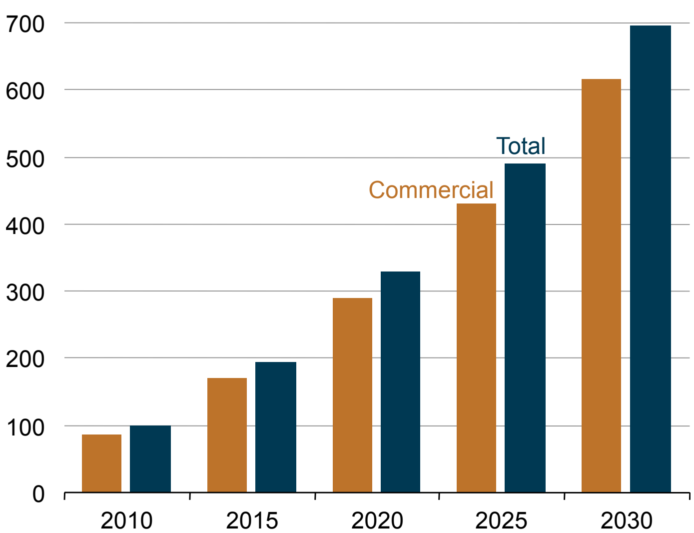
Although Vietnam currently has no nuclear generation capacity, deposits of uranium ore (U3O8 content greater than 0.015%) in the northern and central regions are estimated at 660 million pounds.[242] Vietnam's nuclear fuel-cycle policy calls for survey and exploration of its uranium reserves to determine whether domestic uranium can be used to produce fuel for nuclear power plants.

Economic transition

Vietnam is developing its industrial sector, with the intention of pursuing a larger share of Asia's export market for manufactured products. Bloomberg News reports that, among the Association of Southeast Asian Nations (ASEAN), Vietnam was the largest exporter to the United States in 2014. The gain is attributable to Vietnam's comparatively young work force and relatively low wages.

Vietnam entered the World Trade Organization (WTO) in 2007 and became an early negotiating partner in the Trans-Pacific Partnership (TPP) in 2010. Vietnam's gross domestic product (GDP) growth was estimated at 6.4%/year in 2014, and it is projected to remain above 5.0% through 2030.[243] Rapid economic growth, along with industrialization and export market expansion, has spurred domestic energy consumption. The nation's General Statistics Office (GSO) projects annual increases in commercial sector electricity demand, from 169.8 billion kWh in 2015 to 289.9 billion kWh in 2020 and 615.2 billion kWh in 2030. The GSO also forecasts increases in electricity generation, from 194.3 billion kWh in 2015 to 329.4 billion kWh in 2020 and 695.1 billion kWh in 2030 (Figure 5-17).[244]

Figure 5-17. Electricity demand in Vietnam, 2010–30 (billion kilowatthours)



[237] Japan External Trade Organization, "Vietnam Energy Map" (2010), http://www.jetro.go.jp/ext_images/jfile/report/07000429/vn_energy_map.pdf.

[238] BP, *BP Statistical Review of World Energy* (June 2015), http://www.bp.com/en/global/corporate/about-bp/energy-economics/statistical-review-of-world-energy.html.

[239] BP, *BP Statistical Review of World Energy* (June 2015). A metric ton, or tonne, is equal to 1,000 kilograms, or approximately 2,204.6 pounds (1.10 U.S. short tons).

[240] BP, *BP Statistical Review of World Energy* (June 2015).

[241] American Chamber of Commerce in Vietnam, "ExxonMobil natural gas find increased Vietnam's proved reserves by 30%; to support major energy FDI in Central Vietnam" (not dated, accessed August 24, 2015), http://www.amchamvietnam.com/30443603/exxonmobile-natural-gas-find-increased-vietnams-proved-reserves-by-30-to-support-major-energy-fdi-in-central-vietnam/.

[242] International Atomic Energy Agency, *Country Nuclear Power Profiles 2013 Edition,* "Vietnam" (April 2013), http://www-pub.iaea.org/MTCD/Publications/PDF/CNPP2013_CD/countryprofiles/Vietnam/Vietnam.htm.

[243] Internal U.S. Energy Information Administration data, supplied by General Statistical Office, Vietcombank, and Haver Analytics (June 19, 2015).

[244] International Atomic Energy Agency, *Country Nuclear Power Profiles 2013 Edition,* "Vietnam" (April 2013), http://www-pub.iaea.org/MTCD/Publications/PDF/CNPP2013_CD/countryprofiles/Vietnam/Vietnam.htm.

Future electricity generation

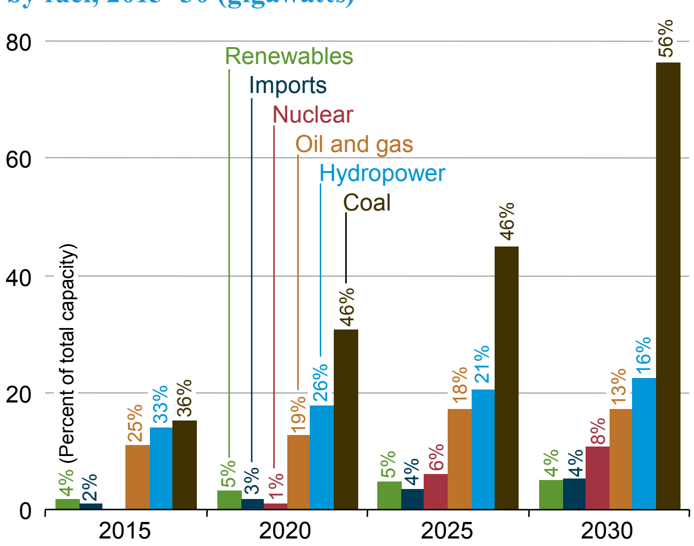
PetroVietnam is seeking to import 11 million tons of coal per year starting in 2017 to supply the domestic power industry, according to a PetroVietnam Power and Coal Import and Supply Company official quoted by Reuters.[245] The coal imports would supply three power plants—two in the southern Mekong Delta and the third in the northeastern province of Quang Ninh.[246]

Vietnam's 2011 Gas Master Plan includes initiatives to promote natural gas in the primary energy mix, targets for natural gas production and consumption, and detailed infrastructure construction plans for natural gas gathering systems, pipelines, and processing facilities.[247] In addition, the government has considered importing LNG in the southern part of the country to meet growing demand for natural gas. PetroVietnam Gas, a subsidiary of PetroVietnam, has signed a memorandum of understanding (MOU) and a front-end engineering and development (FEED) contract with Tokyo Gas Company to develop the Thi Vai LNG terminal in the Vung Tau province, which is expected to be operational by 2017. Also, in March 2014 PetroVietnam Gas signed a natural gas sales and purchase agreement with Gazprom of Russia. Under the agreement, PetroVietnam Gas will receive 48 Bcf/year via the Thi Vai LNG terminal.[248] A second terminal, Son My LNG, is planned to open in 2018, although its construction has not been started.

Vietnam also plans to build the first nuclear reactors for power generation in Southeast Asia. In 2010, Russia's Atomstroyexport agreed to build two 1,000-MW reactors on the Nin Thuan 1 site at Phuoc Dinh. Japan followed in 2011 with an agreement to build Nin Thuan 2 at Vinh Hai. However, the 2011 Fukushima accident delayed construction plans for both projects. Safety concerns contributed to a postponement of the construction start for the Nin Thuan 1 project until 2020. Vietnam continues to work closely with the International Atomic Energy Agency (IAEA) to develop its nuclear infrastructure and to address issues such as siting, stakeholder involvement, industrial involvement, and environmental protection.[249]

Vietnam also plans to build Asia's first offshore wind farm. In March 2015, the United States Trade and Development Agency (USTDA) awarded a feasibility study grant for Phase III of the Bac Lieu Wind Farm, located in a submerged coastal area of the Mekong Delta. Phase I of the project, rated at 16 MW, was completed in May 2013; the scheduled 2016 completion of Phase II, rated at 67.2 MW, will result in a total capacity of 83.2 MW. Phase III, still in the conceptual and early planning stages, has a proposed capacity of 300 MW.[250] The USTDA grant will help Vietnam address the technological challenges of implementing Phase III, which include wind assessments, permitting and land control issues, and electrical grid interconnection.[251] In addition to the Bac Lieu project, the Tay Nguyen Wind Farm broke ground in March 2015. The facility, located in the central highlands, has a design capacity of 120 MW and an estimated cost of $279.62 million (U.S. dollars). The GSO estimates that hydropower will represent a smaller share of Vietnam's power generation mix as other technologies come online (Figure 5-18).

Figure 5-18. Vietnam electricity generation capacity by fuel, 2015–30 (gigawatts)



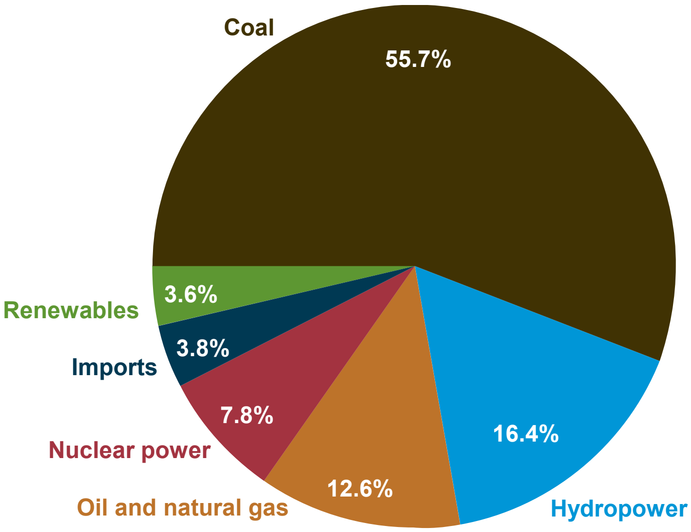
In the IAEA 2013 Vietnam Country Nuclear Power Profile, Vietnam reported that its generation capacity mix will change significantly by 2030, with coal-fired generation projected to dominate the country's total installed capacity. GSO projections indicate that coal-fired capacity will increase from 36% of Vietnam's total net generation capacity in 2015 to 56% in 2030, hydropower capacity will decrease from 33% of the total in 2015 to 16% in 2030, oil- and gas-fired capacity will decrease from 25% in 2015 to 13% in 2030, and nuclear power plants will provide 8% of total generation capacity in 2030 (Figure 5-19).

Challenges

Vietnam faces several challenges to its planned electric power system transformation. The state-owned utility, Electric Vietnam (EVN), is pursuing the dual challenge of installing additional capacity while modernizing the country's transmission and distribution (T&D) infrastructure. In addition, EVN must deal with the effects of the monsoon

[245] Reuters, "Petrovietnam to import coal from 2017 for power plants" (February 10, 2014), http://www.reuters.com/article/2014/02/10/vietnam-coal-import-idUSL3N0LF36Y20140210.
[246] IHS Energy (subscription site), "Vietnam raises coal imports to supply ballooning power capacity" (February 12, 2014).
[247] IHS Energy (subscription site), "Vietnam's gas master plan: prospects and challenges" (August 8, 2012).
[248] IHS Energy (subscription site), "Vietnam signs LNG sales and purchase agreement with Gazprom" (March 7, 2014).
[249] A. Starz and B. Lecossois, "IAEA Reviews Viet Nam's Nuclear Power Infrastructure Development" (International Atomic Energy Agency: November 18, 2014), https://www.iaea.org/newscenter/news/iaea-reviews-viet-nams-nuclear-power-infrastructure-development.
[250] "Bac Lieu Province Wind Power Plant – phase III," 4COffshore webpage (2015), http://www.4coffshore.com/windfarms/bac-lieu-province-wind-power-plant----phase-iii-vietnam-vn03.html.
[251] United States Trade and Development Agency, "USTDA Strengthens Support of Wind Power Development in Vietnam" (March 26, 2015), http://www.ustda.gov/news/pressreleases/2015/SouthAsia/Vietnam/PressReleaseUSTDAStrengthensSupportofWindPowerDevelopmentinVietnam_032615.asp.

Figure 5-19. Vietnam projected electricity generation capacity by fuel, 2030



season, which brings 8 to 10 severe storms annually, with wet foliage, flash floods, and mudslides threatening the reliability of the country's interconnected power system.[252] Another challenge facing Vietnam's electric power sector is attracting the capital needed to finance projects that require large upfront capital expenditures and long lead times to complete, such as the planned Ninh Thuan nuclear power plant project. Developing the necessary T&D infrastructure, creating a stable economic environment to support large projects with longer cost recovery periods, and securing international investment will be critical to Vietnam's ability to achieve its goals of industrialization and energy security.

[252]World Bank, "Projects and Operations: Transmission Efficiency Project (TEP)" (2015), http://www.worldbank.org/projects/P131558?lang=en. The TEP has committed $500 million (U.S. dollars) toward increasing transmission and distribution capacity and reliability in Vietnam.

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